Market Analysis and Business Models

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This work has been carried out by:

WP	*7*	
WP, Task number	*7.2*	
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Executive Summary

The RES4BUILD project aims to mitigate Global Warming Potential in the built environment through renewable energy systems. As part of the project, an Integrated Energy System (IES) was developed from multiple innovative components, using advanced numerical tools to optimize both the design and use of the integral system. Intense collaboration with end-users is used to assess the applicability of the system as a whole and their components, preparing for smooth market adaptation.

Task 7.2 'Market analysis and business models' analyses 8 specific potential markets in the EU to enhance adaptation and prepare for business cases to assure optimal use of the system in each target market. Through this, the outcomes of Task 7.1 - in which simulations show the possible technical GWP reduction impact of system implementation, are placed into perspective. These provide an indication of which markets are more or less applicable for the system as a whole and which are most feasible to prioritize.

Business Model Canvas*:* for this study, an existing business model framework is applied. This supports the exploration of all aspects of a business model, finding solutions in a wider space than just financial and technical. This aligns with the findings of the co-creation research in Work Package 4, which concludes in the need for a push in collaboration with local partners and their communities. The 'Business model Canvas' is applied throughout this study and has shown to be practical and informative. Therefore, it is advised to apply it in further detail, as will be planned out in the last task 7.3 'Roadmap'.

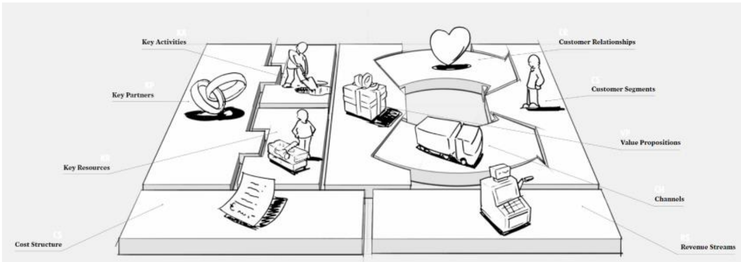


Figure 0-1: Business model canvas

Market analysis As the scope of this study was aimed at 8 EU-countries, it was decided that a recap of the current and upcoming EU-legislation pertaining to energy use in buildings was needed to identify areas of commonality across the legislation.

Multiple approaches led to the conclusion of which countries, regions, building typologies and ownership types are most applicable to prioritize when preparing the roadmap. This is done by (1) data analysis on building stock size and quality, (2) questionnaires and interviews with experts in the target markets, (3) market analyses by local practitioners and (4) reviews by the local RES4BUILD project partners.

Data model: The large amount of information from the market analysis is saved in a data-model, which is proposed to be the basis for further development in the future. This model links the requirements of EU and local regulation, with land and socio-economic aspects to the Business Model Canvas segments. By making these links, a bridge was made between the regulatory landscape and the business environment into which these IES solutions are being introduced. When considering the adoption of an IES solution, the use of this data model will help to reduce the implementation program through raising awareness of key barriers and supports.

System analysis & operational performance*:* the systems are defined in 'hardware', 'software' and 'orgware' which need to be coordinated with each specific building application to successfully contribute to the complete IES.

System components	Modelling & Control	Market approach
Hardware	*Software*	*Organization*
Magneto Caloric Heat pump Multi Source Heat pump PVT panel Borehole Thermal Energy Storage (BTES) Storage/Buffer water tanks	BTES Controller Grey box model White box model BMS / BEMS optimization	Integrated Energy System Pilot Studies Financing models

Figure 0-2: RES4BUILD System; system organization based on 'City at eye level' publication

The previous outcomes of the RES4BUILD deliverables were assessed through the lens of a Business Model Canvas. For each system, the extent to which the technology is applicable and what gaps need to be planned for during the roadmap (D7.3 phase) are identified in order to meet with market expectations while complying with the user needs. The systems are mapped per country, showing their applicability based on the capacity needs and renewable generation capacities. Applying these bespoke conclusions to the previous outcomes of T7.1, shows that enhanced performance is possible, while considering operational and embodied carbon for these systems.

Warm Climate	**Greece Spain Italy**	**Res : ASHP + PVT (no BTES)**	SFH
			MFRB
		Non-Res: ASHP & PV	Office
			School
Moderate Mixed	**Ireland**	**Res : ASHP + PVT (no BTES)**	SFH
			MFRB
		Non-Res: ASHP & PV	Office
			School
Average	**Netherlands Germany**	**Res : MSHP + PVT + BTES**	SFH
			MFRB
		Non-Res : MSHP + PVT + BTES	Office
			School
Cold	**Poland Denmark**	**Res : MSHP + PVT + BTES**	SFH
			MFRB
		Non-Res : MSHP + PVT + BTES	Office
			School

Figure 0-3: Bespoke RES4BUILD configurations

Prioritized Customer Segments & Business models: The three parts (business models, market analysis and system analysis for operational performance), were adopted in three prioritized markets which are proposed as exemplars for further development during the roadmap. In doing this, the Business Model Canvas and the data-model for translating the policies landscape into business were tested. The prioritized customer segments are:

1. Poland, single family houses in rural areas, which are privately owned.
2. Greece, multi-family residential buildings in urban regions, privately owned and targeted to low-income residential groups.
3. Spain, public office buildings which are owned and occupied by the same institute and located in urban areas in climate zones which require both heating and cooling.

It is concluded that this approach is beneficial for mapping aspects of innovative integrated energy system design and has potential for further development. It is considered that these business models are in an early stage of development. Recommendations for future optimizations are given:

- In the system analyses: describing the relevant additional assessments or improvements, to comply with market or regulatory policy requirements
- In the business models: providing suggestions for improvements on a more detailed level per country and taking into account non-HVAC aspects such as energy net metering, electric vehicle charging in buildings, and retrofit market trading participants

- In the frameworks: for those presented as applicable to the various scenarios - have been tested while preparing this market analyses review but are in need of continuous update and refreshment for dissemination and awareness raising support.

Abbreviations

BEMS	*Building Energy Management System*
BMS	Building Management System
BTES	Borehole Thermal Energy System
COP	Coefficient of Performance
DBFMOD	Design, Build, Finance, Maintain, Operate and Deconstruct
DHW	Domestic Hot Water
EaaS	Energy as a Service
ECM	Energy Conservation Measure
EPC	Energy Performance Certificate (note in Ireland this is BER – Building Energy Rating)
ESCO	Energy Service Company
ESS	Engineering Equation Solver
GSHP	Ground Source Heat Pump (normally water source – open or closed loop)
GWP	Global Warming Potential
HVAC	Heating, Ventilation and Air-Conditioning
IES	Integrated Energy System
MFH	Multi-Family Home
MFRB	Multi-Family Residential Building
MCHP	Magnetocaloric Heat Pump
MSHP	Multi-Source Heat Pump
NZEB	Nearly Zero Energy Building
ODP	Ozone Depletion Potential
PVT	Photovoltaic Thermal
SFH	Single-Family Home
TRL	Technology Readiness Level
WLCA	Whole Life Cycle Analysis
ZEB	Zero Emissions Building

1 Introduction and outline

1.1 Scope

This assessment builds on the earlier work in Task 7.1, which is concluded in the *D7.1 Project Impact.* The work includes a mapping of building stock over the EU28 countries and indicates the maximum possible impact which could be achieved if all this stock would be renovated to cost-optimal building standards, applying the full RES4BUILD Integrated Energy System. The possible impact on reduction of **GWP is estimated to be 88%,** compared to the baseline assumption that these NZEB (Net or Nearly Zero Energy Buildings) renovated buildings would be served with a gas fired boiler and / or air conditioner for relevant climates. The assessment was done for the relevant building typologies (4 in total) and 4 climatic zones.

This is per definition a theoretical scenario as there are many factors influencing the actual GWP reduction, which could end up higher or lower than the indicated 88%:

- *Not all buildings in the EU28 will be fit to renovate to cost-optimal insulation levels. Due to monumental value or simply ownership.*
- *People will not use their buildings as planned. Some will open the windows on hot days, losing the valuable cooling or heating energy.*
- *Energy prices and policies will push people in deciding to implement the system or hold them back.*
- *Climate change could increase cooling needs and limit heating demands and will cause extreme conditions which could cause systems to failure or underperformance.*
- *Many more aspects could be described influencing the actual performance.*

This report will therefore define the most influential parameters which are key to application and optimal use of the systems. These are reviewed against the property markets in the climatic regions to conclude which conditions are best to pave the way of implementation. The question is therefore **which business models lead to the optimal potential of the system components**.

Some definitions are required to clarify the width of scope:

- Description of the **RES4BUILD system** – refer to section 1.1.1
- Content of the **business model** – refer to section 1.1.2
- **Shape and size of the system** and components under review – refer to section 3

1.1.1 RES4BUILD system

The RES4BUILD systems consists of a number of innovative **components**, a specific **modelling & control methods** for performance prediction and optimization and a **market approach**, based on lessons learned from actual and simulated cases. Below table summarizes these elements:

Table 1-1: RES4BUILD System; system organization based on 'City at eye level' publication

System components	Modelling & Control	Market approach
Hardware	*Software*	*Organization*
Magneto Caloric Heat pump Multi Source Heat pump PVT panel Borehole Thermal Energy Storage (BTES) Storage/Buffer water tanks	BTES Controller Grey box model White box model BMS / BEMS optimization	Integrated Energy System Pilot Studies Financing models

These aspects support the following goals:

- innovative hybrid solar energy collectors, PV and thermal, to generate both electricity and heat simultaneously,
- testing of new technology magneto-caloric heat-pumps that have potential for high coefficients of performance (CoP),
- development and testing of new multi-source heat pumps based on the vapour compression cycle with low-GWP refrigerants that select the heat source or sink according to the most favourable one to maximise the CoP, and
- development and testing of intelligent control optimisation software that seeks to enable a building's energy systems (heat and power) to respond to the variable demand and supply conditions being placed on the electricity grid.

1.1.2 Business models

1.1.2.1 Frameworks

Business models come in various shapes and forms. This study aims to explain the general approach to business models, while using existing data sources to fill in the details. The result of this study will not be a final business model for the complete RES4BUILD-concept in 8 countries, but more a **methodology**, guiding the future product developers of this system/approach to prepare their specific approach to each property type, location or customer.

Table 1-2: Examples of business models for innovative technologies

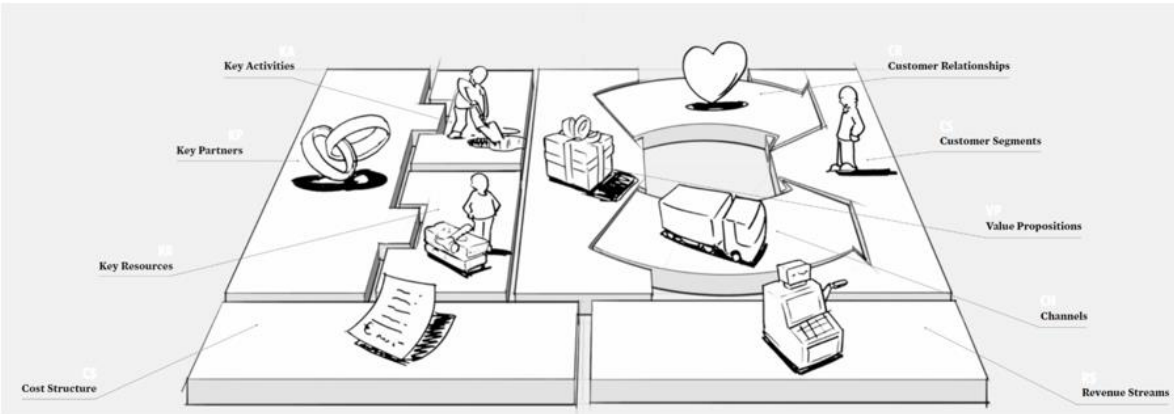
Source	Summary
IndustrRE, Business Models and market Business http://www.industre.eu/downloads/download/business-models-and-market-barriers	Business models are understood as a set of **flexibile** business strategies in relation to **demand** in order to generate **economic benefits.** The strategies arise from a **combination** of instruments, where economic benefits are obtained from different sources of revenue and savings. This results in a matrix of savings/revenue on the one hand and available tools on the other hand. This approach is therefore limited to financial and technical aspects.
Arup, The road from 2018 to 2035: Business Models The Road from 2018 to 2035 Business Models - Arup	Analyzing the old electricity supply model and comparing to alternatives such as Energy Service Company's (ESCO), Local Energy Communities, Peer-to-peer trading, Hydrogen storage, energy Distribution System Operators (DSO's), Vehicle-to-grid or Transport as a Service (TaaS). These include the required **hardware** for transport of energy, metering systems and generation. Also includes required **data environments** for optimization of performance. Through the technological aspects the **contractual and economic** benefits for end users and suppliers are explained.
CE100, BAM, Arup: Circular business models for the built environment Circular Business Models for the Built Environment - Arup	An approach to Circular Business Models (CBM's) is presented which allow the retention of an asset (e.g. a building) at its highest value over time and support enhancement of natural capital. This approach therefore has a wider view than the above-mentioned models focused on the financial & technical aspects. These business models would allow for: - Greater control of **resource** streams - **Innovation** through the supply chain - Enhanced **collaboration** within the supply chain - Services that **capture valuable** products / resources These models could cover the range of design, use and recovery stages of a lifecycle. In each stage focusing more or less on the Social, Technical and Financial aspects.

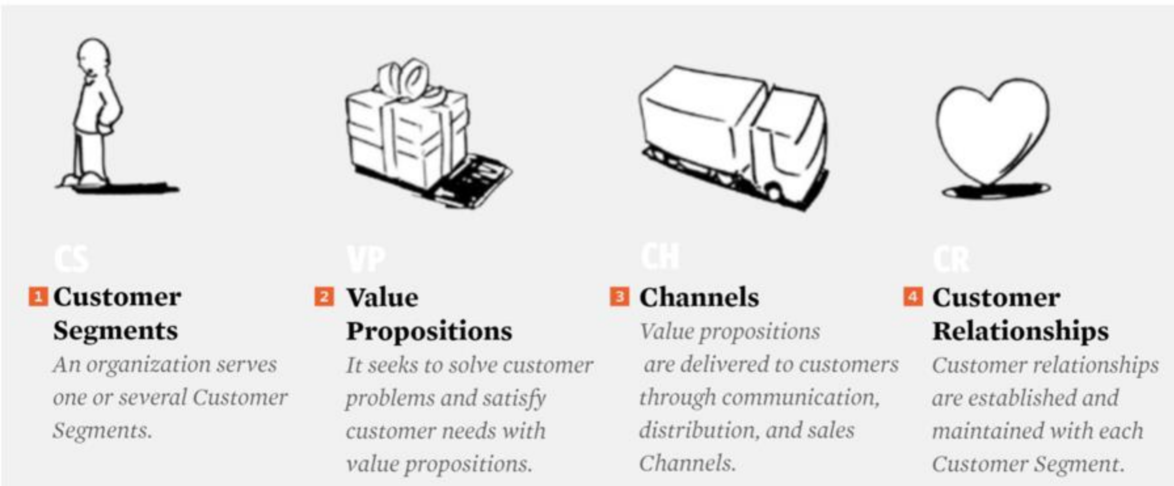
Most of the listed examples focus on financial and technical aspects. The Circular Business Model approach prepares for a wider view, but is limited in the definition of the customer or market segment.

This aspect is key to define which technology to select, or in the case of RES4BUILD: which combination of components is relevant. Probably, the complete RES4BUILD-concept will not be applicable for all property types, for some market segments only certain parts of RES4BUILD will be applicable. The business models will therefore be defined by:

- Definition of the stakeholders: key partners, targeted residents or building owners;
- Definition of the market segmented: property location and typology;
- Value proposition, based on system description, benefits and barriers
- Service approach, including key activities, resources and channels
- Organizational strategy, including (environmental) cost structure and revenue streams

This is captured in a widely used approach using the 'The Business Model Canvas'. The Business Model Canvas was developed by business strategists Alexander Osterwalder and Yves Pigneur, and was described in their book Business Model Generation.





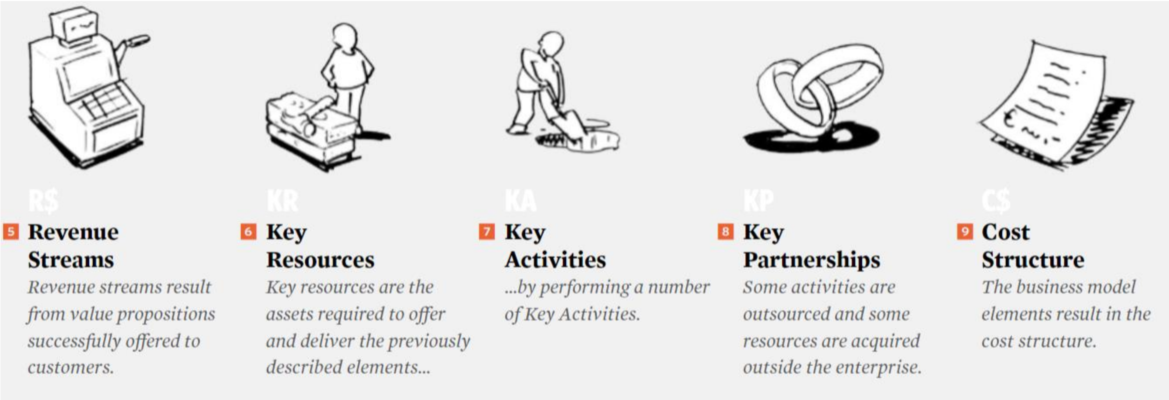


Figure 1-1: Business Model Canvas, as published by Strategyzer (https://www.strategyzer.com/books/business-model-generation)

1.1.2.2 What's missing?

Keen-eyed observers and long-time users of the Business Model Canvas will note many missing elements. What about the identity and trust of the organisation? How will the business be governed? What about sustainability?

These gaps need to be filled and the following should also be added to the thinking around the Business Model Canvas for the most complete strategy:

- **Organization brand** – who is the organization that operates this business? What is its culture, history and purpose?
- **Governance and enablement** – how will the organization govern and enable this business?
- **Objectives and key results** – how will the organization set the objectives and assess the success of the business?
- **Context, trends and externalities** – what is the city, place and market context of the business? What trends will affect its prospects? What externalities will shape its success?
- **Sustainability and ESG risk** – what are the sustainability and ESG risk considerations for the business?

This is why for the business case definition in this research, a 'foundation layer' will be added to the canvas, to capture the above relevant parameters:

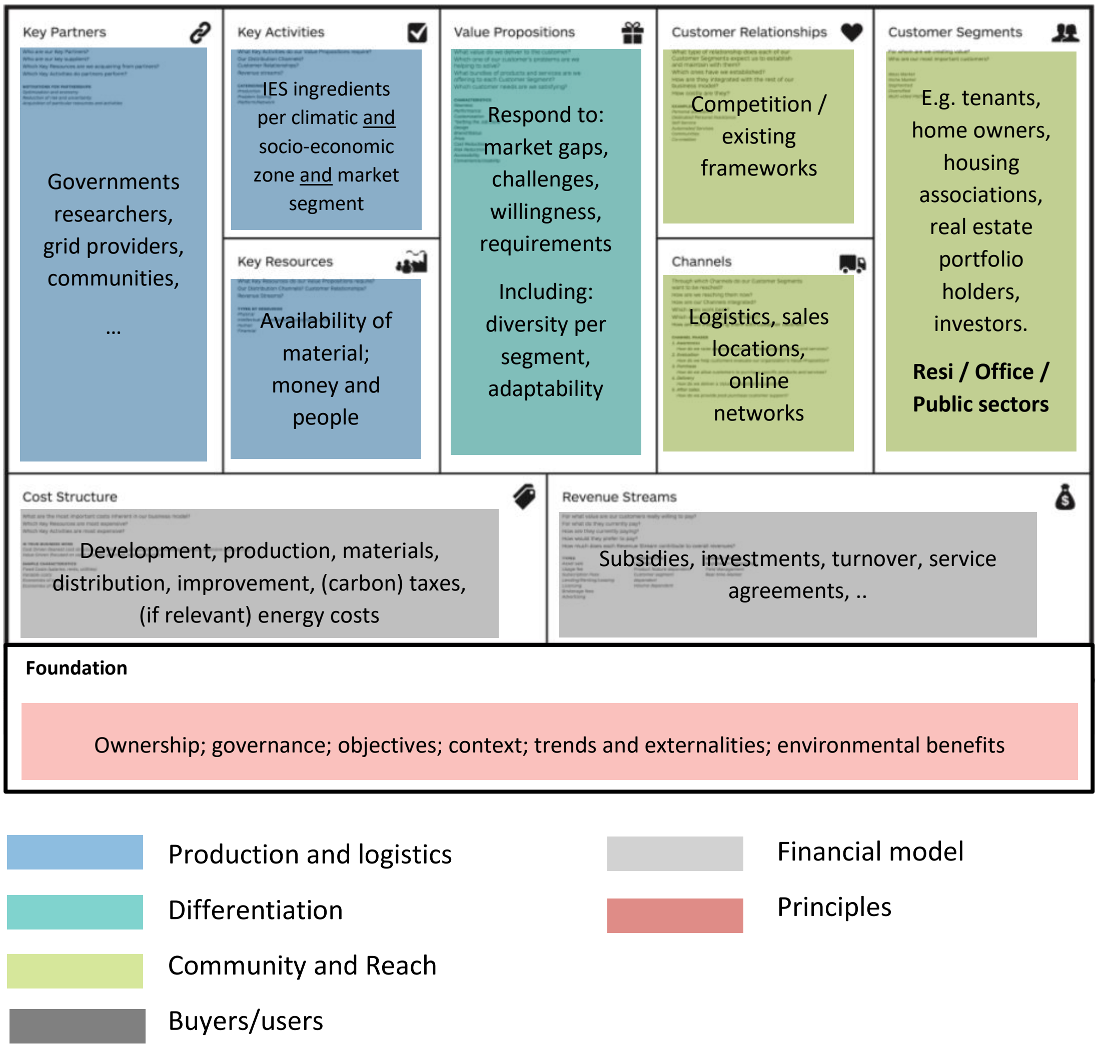


Figure 1-2: RES4BUILD Business Model Canvas

1.1.2.3 Steps

This research covers only some aspects of the full methodology. Some of these aspects will be part of other Work Packages or fall outside of the RES4BUILD scope. The table below shows these aspects (or phases) and explains which are covered in this study.

Table 1-3: Business Model development steps

	Mobilize	**Understand**	**Design**	**Implement**	**Manage**
Objective	Preparation of the business model project	Research and analysis of elements needed for the business model	Generate and test viable business model options, select the best	Implement the selected business model in the field	Adapt and modify the business model in response to the market reaction
Focus	Setting the stage	Immersion	Inquiry	Execution	Evolution
RES4BUILD scope	WP7.2 (and prev.)	WP7.2	After RES4BUILD	After RES4BUILD	After RES4BUILD
Methodology	Definition of the business model and its ingredients.	Review previous WP's on lessons learned and analyze EU market. Use questionnaires to inquire knowledge. Sketch the business models	Generate **scenario's** and further develop the business models market experts. Hold workshops to discuss the robustness.	-	-

1.2 Methodology & reading guide

To define these possible business cases, sub-tasks have been defined at project start. Based on the actual progress and learnings throughout the project, these tasks are interpreted and grouped in specific steps in this Market Analysis, which also forms the reading guide.

Tasks 7.2 Scope	Report Outline & methodology
The 8 markets of will be analyzed in order to identify where the opportunities and the challenges lie for the up-take of the developed systems. The elements of the market to be studied in each of the target countries are outlined below: • Size and age of the building stock in the country • Policies of local, regional and national authorities relating to zoning, planning, grants, funding, incentives • Building codes and building regulations • European Directives (EPBD recast 2, EED, RED II, etc) • Energy market rules and tariff regimes, for example feed-in tariffs, self-consumption regulations, balancing market rules, the market for aggregators and the calculation of network tariffs • Cultural, economic and social aspects of financing and developing new buildings and refurbishment of old buildings. How are the barriers associated with the landlord / tenant relationship overcome in the delivery of systems in buildings that are optimized for occupier and environmental benefit?	Chapter 2: Market Analysis As the listed countries all are part of the EU, this analysis starts with insight in the size and type of building stock. From here, focus is given to most relevant market segments to target first. Following this focus, a deep analysis of EU-wide policies explains the framework for decision-making in individual countries. By using questionnaires with Arup experts in the listed countries & regulatory analyses by their teams, information is be collected on the listed elements for the market study. This supports the future setup of business models by initial links to regulation and provides an overview of the market potential of the IES. The overview is based on a detailed assessment of the requirements for the business model, which follow from either EU- or local requirements. This forms a 'program of requirements' to which the value proposition (combination of the RES4BUILD aspects) should provide an answer.
Then, the results of tasks 3.4/7.1 and the energy market rules of each country as identified within that task will be used to analyze and evaluate the different possible system designs and operational strategies.	**Chapter 3: System analysis** Each system is assessed on their contribution to the business model. This is done through detailed questionnaires and interviews with the partners, application of the EU taxonomy and through review of the previous deliverables. This section explains the opportunities and barriers for each aspect.
	Chapter 4: System designs and operational strategies Based on outcomes from the Market analysis and the System analysis, optimised configurations for system designs and operational strategies for target markets are identified. For specific configurations of the IES, simulations indicate the impact on GHG-reductions.
The most suitable business models per country will be identified and described, helping decisions that have to do with issues such as: • Storage or generation components oversizing vs. energy exchange with the grid • Use of demand and generation flexibility within the building vs peer-to-peer trading vs supply services to the grid	**Chapter 5: Business models** The result is an example of the business models for customer segments with highest priority, applying a good spread over the climate- and country zones. These include the applicable RES4BUILD technologies, the integration in existing buildings, the customer relation and required relations to stakeholders. Thereby also responding to the energy grid capacity and adaptability over time.

1.2.1 Collaboration

ARUP will be the task leader with full responsibility for the work to be carried out. JIN and BAPE will provide input for the markets of the Netherlands and Poland respectively, based on information collected in WP4. NCSRD and PSYCTO will support the data collection in Greece and HIG will support the data collection in Sweden. NCSRD, WIP and VITO will support ARUP on the definition of the business model. The table below shows the focus countries and hierarchy of information.

No.	0	1	2	3	4	5	6	7	8
Market	EU	Germany	Greece	Ireland	Italy	Netherlands	Poland	Spain	Denmark
Primary analysis	Arup	Arup	Arup	Arup	Arup	Arup	Arup	Arup	Arup
SUPPORT	WIP	USTUTT	NCSRD PSYCTO	ERINN WIP	-	JIN	BAPE	MG Sus.	DTU DTI
Building Stock	x	x	x	x	x	x	x	x	x
Policies	x	x	x	x	x	x	x	x	x
Building Codes	x	x	x	x	x	x	x	x	x
Energy market rules and tariff regimes	-	x	x	x	x	x	x	x	x
Cultural	-	x	x	x	x	x	x	x	x
Economic	-	x	x	x	x	x	x	x	x
Social	-	x	x	x	x	x	x	x	x

2 Market analysis

2.1 Methodology

Eight markets are analyzed to identify the opportunities and the challenges for the up-take of the developed systems. The elements of the market studied in each of the chosen representative EU countries are outlined below:

- Size and age of the building stock in the country
- Policies of local, regional and national authorities relating to zoning, planning, grants, funding, incentives
- Building codes and building regulations
- European Directives (EPBD recast 2, EED, RED II, etc)
- Energy market rules and tariff regimes, for example feed-in tariffs, self-consumption regulations, balancing market rules, the market for aggregators and the calculation of network tariffs
- Cultural, economic and social aspects of financing and developing new buildings and refurbishment of old buildings.

For analysis, local experts from Arup were consulted through an internal questionnaire, including questions on all above aspects. Based on this input, interviews were held with the relevant experts per country, which forms the basis of the market analyses as presented in the **Appendices**.

2.1.1 Size and type of building stocks

The D7.1 report provides an overview of the EU building stock, including the share of typologies, the energy performance, the major energy sources, the estimated heat- or cooling demand and more. To answer the question from business model perspective: which building typologies in which countries are most relevant to start implementation of the propose Integrated Energy System, the analysis below provided insight in:

The market type and size in each country which has enough space availability to fit the relatively complex IES and are most relevant to target, based on their energy-intensity.

In each country, distinction is made between property types as below and assumed the expected quality of building fabric to be energy label B or higher.

- Non-residential property
- Multi-family apartment buildings
- Single-family houses of significant size (e.g. 150m^2 and larger)

This concludes:

- Which countries/zones have the largest property sector where the full IES system is applicable
- Indication of the need for alternative system or business model configurations, such as:
    - Excluding PV(T), as limited roof size available
    - Minimal buffer systems, as property space is lacking (and therefore targeting e.g. district heating connection as ‘buffer system’)
    - Additional insulation requirements (for property with label B or lower).
    - Excluding the cooling options, as limited cooling requirements.

Relevant sources:

- ABIENCE project: overview of EU reference buildings and specifications
- TABULW webtool: providing building stock information and reference buildings
- Odyssee database on country-specific information.

2.1.2 Cultural, economic and social aspects

Cultural, economic and social aspects are described for each country, based on relevant sources for that specific country as can be found in the appendices. Overall information for Europe is also taken from the Cultural-E Atlas (eurac.edu)

2.1.3 Policies and Regulations

Aiming to describing the existing frameworks for building codes, building regulations and policies. Indicating restrictions and incentives, such as spatial or technical limitations and grants, funding or incentives.

- IES Policies database: Policy database – Data and Statistics - IEA
- Eurostat: Database - Eurostat (europa.eu)
    - Policy mapper: Policy Mapper Energy Efficiency Tool (odyssee-mure.eu)
- MURE database: Table configuration in MURE database

From this research, we conclude that there is a lack of overview in the policy landscape. This makes it challenging for building owners, system developers and residents to understand their position and consequences of their decisions. It is understood that market parties (among which: Arup) are filling this market gap by providing sector-targeted overviews. This aims to explain the interaction between the sectors and policies. This includes:

- Market sector, e.g. energy / property and asset management / science and industry / finance / transport and infrastructure
- Phase: strategy / refurbishment / implementation / OandM / Development / Financing / asset management
- Status of the implementation: strategy / early-draft / executed / superseded / concept / draft / enacted-effective / N/A.

See below an example of a sector-targeted overview of policies that affect the ‘energy-in-buildings’ market that Arup has produced:

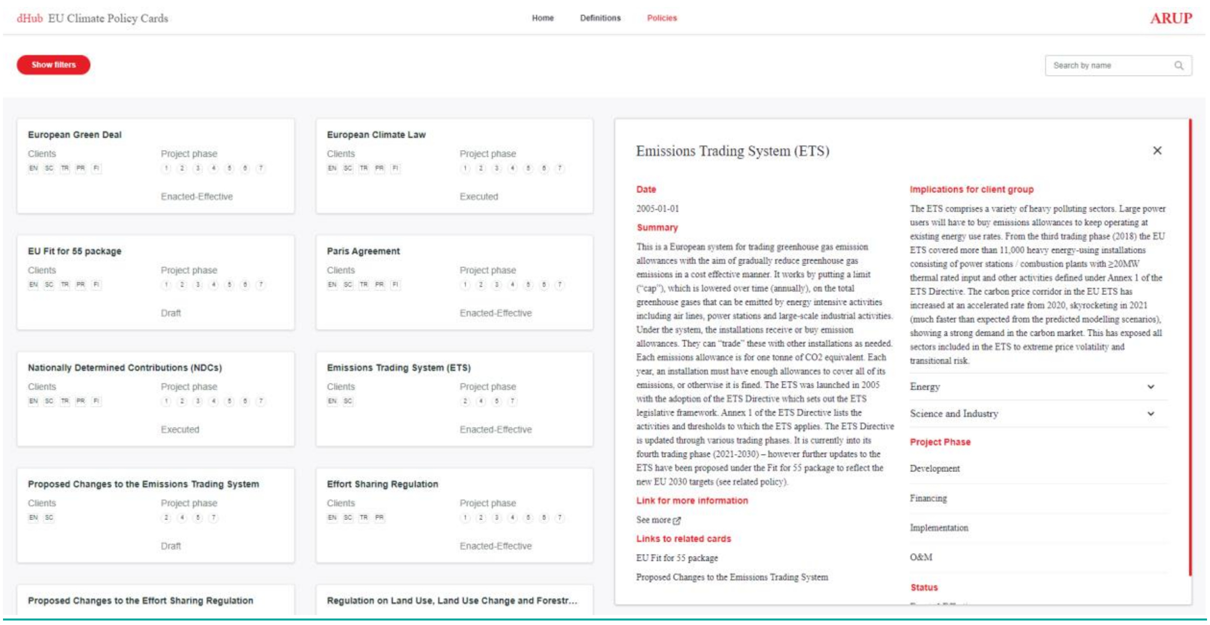


Figure 2-1: Screenshot of Arup's policy overview for market sectors

2.1.4 Energy market rules and tariffs

In 2022, the EU energy market is under review, as result of climate mitigation incentives, the aim for decarbonization, inflation trends and geopolitical instability. In some countries other aspects, such as physical risks from gas extraction are influencing the market (e.g. Netherlands).

For each reviewed country, the existing situation is described and explanations given for which (recent) regulations and policies influence energy investments decisions. Also, the energy market rules and tariff regimes, for example feed-in tariffs, self-consumption regulations, balancing market rules, the market for aggregators and the calculation of network tariffs is explained. If relevant, grid congestion and net metering (payback) will be included.

Relevant sources:

- TKI Urban energy research on smart energy communities: presentation
- Cultural-E deliverable on Local policies and boundary conditions for PEH's

2.2 Size and type of building stocks

2.2.1 Residential

2.2.1.1 Type of dwellings

Single-family homes have the largest share of the residential stock in Ireland (87.2%), Netherlands (70.8%), and Denmark (59.3%); while multi-family homes in Italy (74%), Spain (70.8%), Poland (66.9%), Greece (65.2%), and Germany (54.8%), make up the large share of the stock. In Poland, most of the MFHs are in high-rise buildings with more than 15 dwellings per building (EU Building Factsheets).

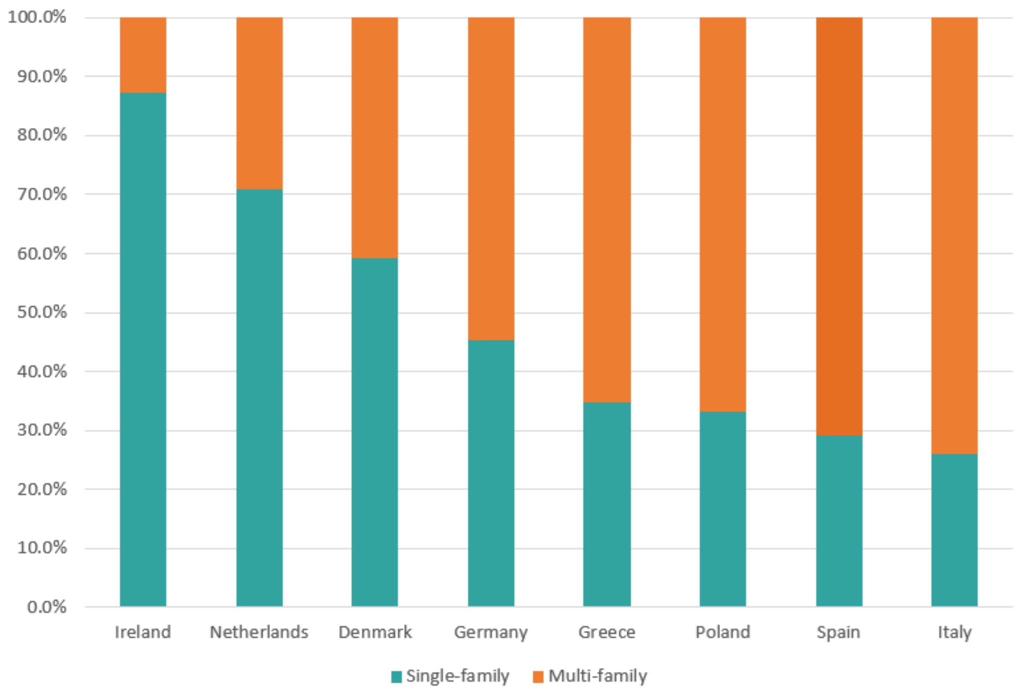


Figure 2-2: Distribution of multi and single-family dwellings (Source: EU Building stock characteristics, 2013)

Large sizes of SFHs can be found in Denmark, Ireland, Netherlands, Spain, Italy, and Germany, respectively. Due to larger area per capita in SFHs, there is more space available that can be used as a potential technical room for the equipment of the IES solution. Therefore, these countries are interesting target markets to apply the IES solution of Res4build. Also, the technical equipment per unit can be larger in size.

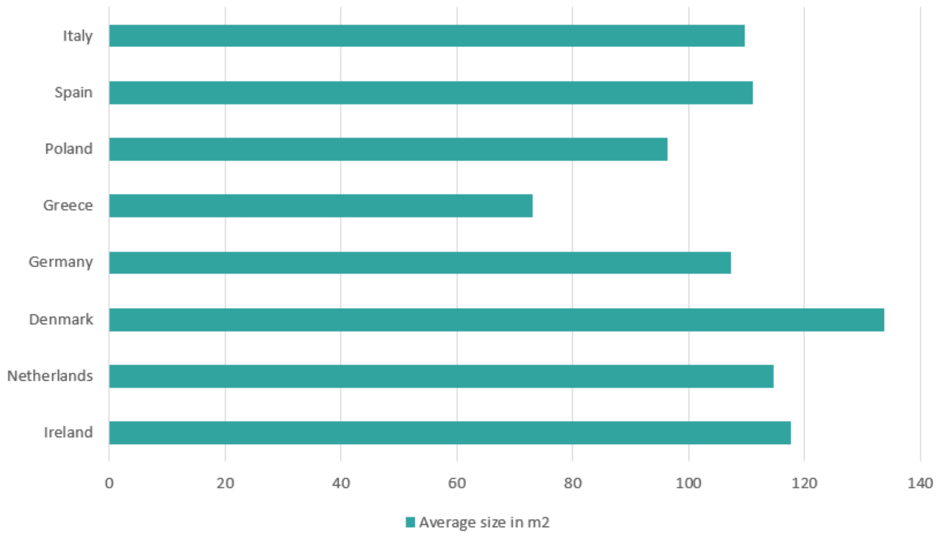


Figure 2-3: Average size of single-family dwelling (Source: Entranze online tool)

In all countries except Greece, SFHs have a larger average size per dwelling than MFHs (Entranze data tool). In general, SFHs in Greece and Poland are smaller in size compared to other countries, but the share of MFHs is dominant in these two countries. As a result, considering a collective central space in multi-family buildings for the application of RES4BUILD in these countries is relevant.

2.2.1.2 Average energy consumption per m^2 residential

According to the EU Building Factsheets, Poland, Germany, and Italy respectively have the highest energy consumption per m^2 in residential buildings (EU Buildings Datamapper). The initial prediction was that this could be a result of large share of MFHs in the residential stock in these countries. However, the simulation outcomes of WP7.1 show that in Germany, Italy, and Spain, single-family homes have a higher total energy demand for heating, cooling, and domestic hot water compared to multi-family dwellings. In these countries, the building skin demand in MFHs is lower than SFHs, while the energy demand for domestic hot water is higher. The rest of the countries have not been simulated in that work package.

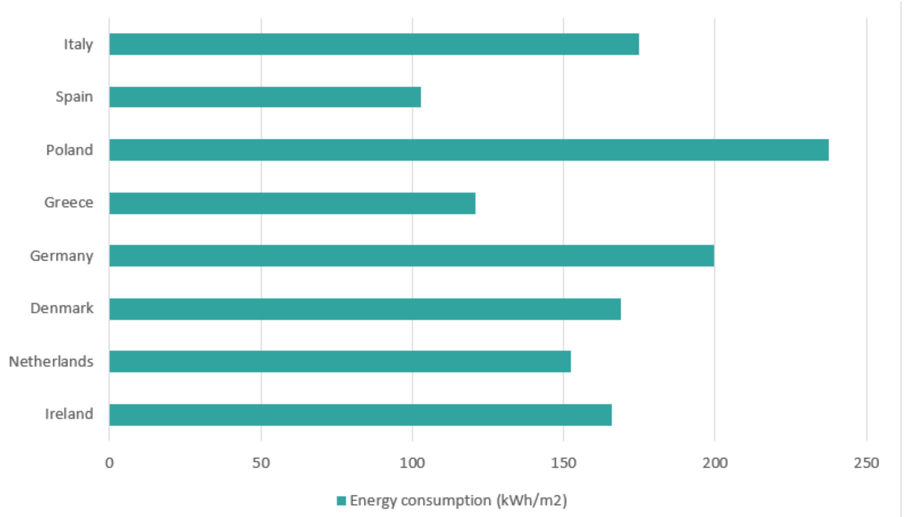


Figure 2-4: Energy consumption of residential buildings per m^2 (Source: EU Building Factsheets, 2013)

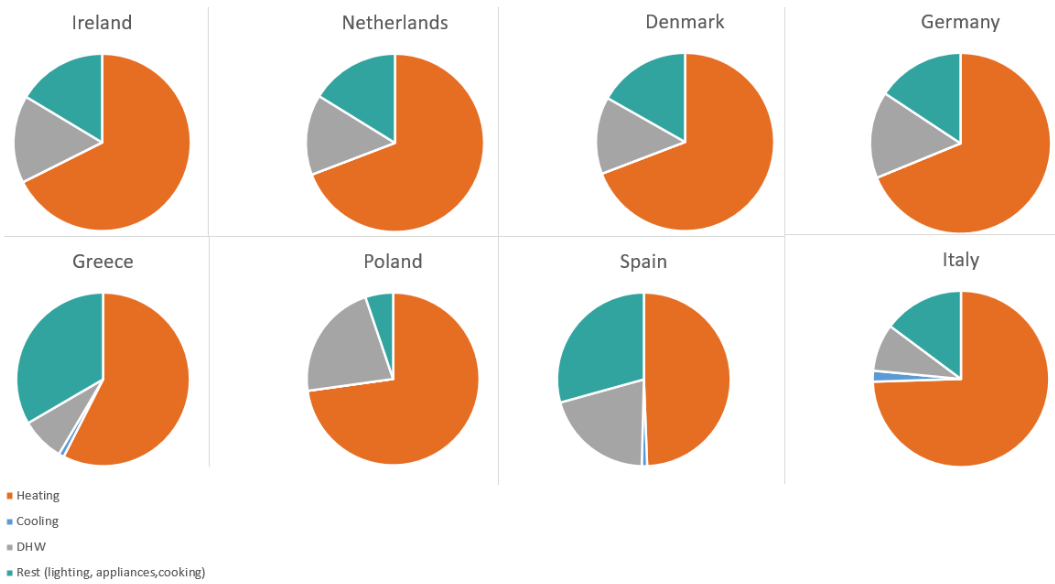


Figure 2-5: Energy consumption by end-use in residential sector per country (Source: EU Building Factsheets, 2013)

Ireland, Netherlands, and Denmark have relatively similar high energy consumption per m^2. In these countries, single-family homes are the dominant share of the residential stock and also have the largest average size compared to other countries. This could explain why residentials in these countries also have relatively high energy consumption per m^2.

From the deliverable outcomes of WP7.1 can be concluded that while the energy demand for domestic hot water is higher in MFHs, the total energy demand is still lower than SFHs.

2.2.1.3 Distribution of population

As services such as district heating/cooling systems are more available in cities and high-density areas, it becomes more relevant to consider the application of IES in suburbs or rural areas.

- In Ireland, Denmark, and Poland, most of the population live in houses in rural areas
- In the Netherlands, majority of the population live in houses in cities. The share of the people living in towns/suburbs is relatively high as well, who also live in houses
- In Greece, the share of people living in cities and rural areas is almost the same. While in cities most of the people live in flats, it is the opposite in the rural areas.
- In Germany, majority of the population live in towns/suburbs and are divided equally between houses and flats. The population located in rural areas live mostly in houses.
- In Italy and Spain, most people live in apartments in cities and people who live in rural areas, reside mainly in houses.

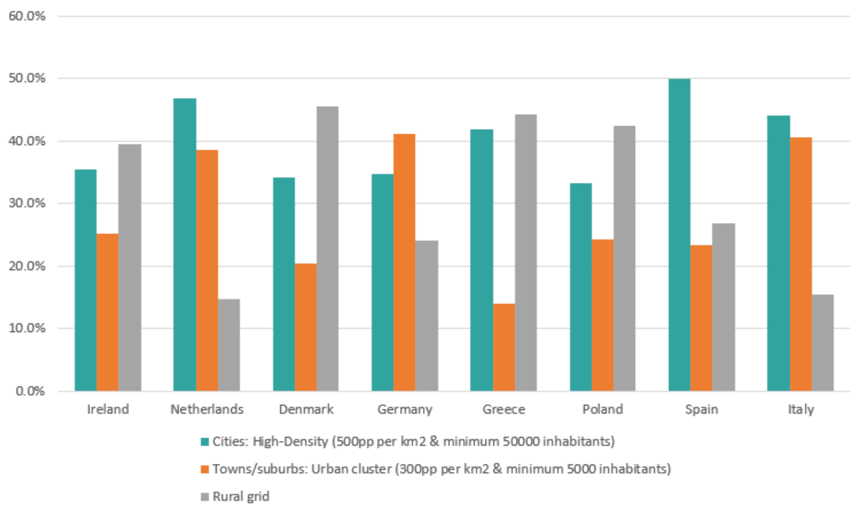


Figure 2-6: Distribution of population by degree of 22rbanization (Source: EU Building stock characteristics, 2013)

2.2.1.4 Typology of dwellings

Terraced (row-house) SFHs have more space limitations compared to detached and semi-detached SFHs. Therefore, the countries with higher share of detached and (semi)detached should be higher prioritized as they have more potential for the application of RES4BUILD system. These countries are Denmark, Ireland, and Germany (Entranze data tool).

Further development of the system could be applicable for row-houses, e.g., by application as a block-system and a collective technical room. Row-houses are the primary SFH typology in The Netherlands.

For the rest of the countries, data on the typology of the dwellings was not available.

2.2.1.5 Type of ownership & tenure

The ownership & tenure indicates the type of business models to apply e.g., stimulation by subsidies for homeowners, legal regulation for private rent (building owners) and energy-as-a-service (EAAS) models for social dwellings as investment budgets are limited.

Dwellings in all countries are mainly owner-occupied. In Germany, the share of owner-occupied dwellings and private rentals are almost the same (Eurostat, 2020). According to OECD (2020), there is a large share of social housing in the Netherlands and Denmark.

Among low-income families, dwellings in most countries are owner-occupied except the Netherlands, Denmark, and Germany which are mainly private renters (Entranze data tool).

2.2.1.6 Type of heating system in dwellings

Countries where collective central systems are widely applied and have a large share of MFH are relevant to target, as well as individual heated locations, which mostly have many SFH's.

Collective central heating is mainly used in Greece and Germany, where there is a large share of MFHs and therefore are relevant to target for the application of IES (Entranze data tool).

Individual heating system is the most common in Ireland, Italy, Netherlands, and Spain, respectively. While in Ireland and Netherlands these are mainly SFHs, there are more MFHs in Italy and Spain (Entranze data tool). Individual heating being more popular in Italy and Spain could be due to possible disputes over costs (operation and maintenance).

According to the D2.3 publication of WEDISTRICT (2020), Denmark is among the countries with large share of district heating, namely more than 50%. Poland and Germany are among the countries with medium share of DH. The rest of the countries have small share of DH.

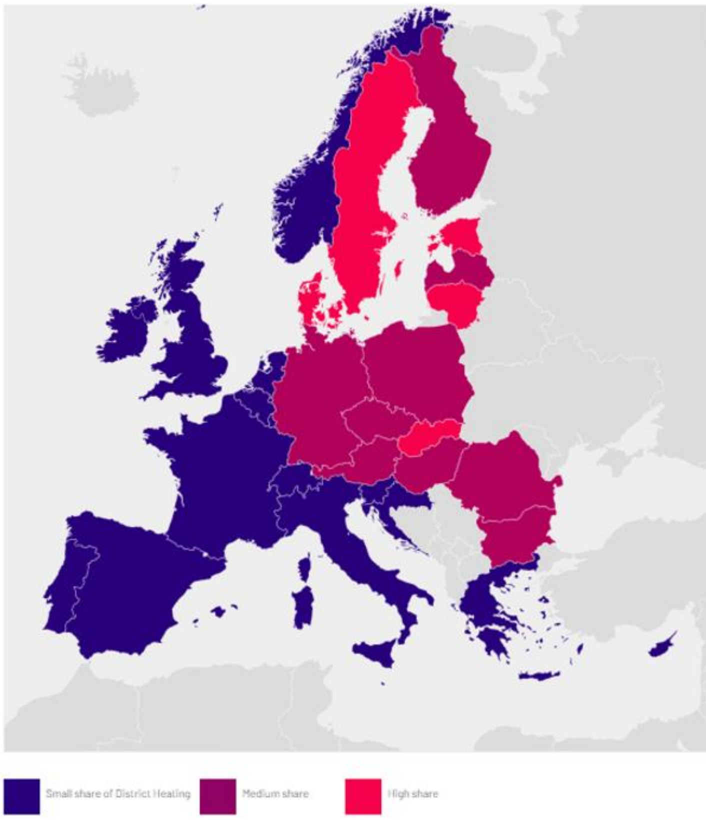


Figure 2-7: Share of district heating across Europe. (Source: WEDISTRICT.EU)

2.2.1.7 Use of non-renewable energy sources

As per the aims of the research, it is most relevant to first target countries which use large shares of non-renewables. Assuming district heating and biomass as renewable or able to transfer to renewable sources on grid level, therefore less short-term need for individual building solutions.

Considering the source of the energy used for space heating, Denmark is the only country which uses more than 50% from the renewable sources (Entranze data tool).

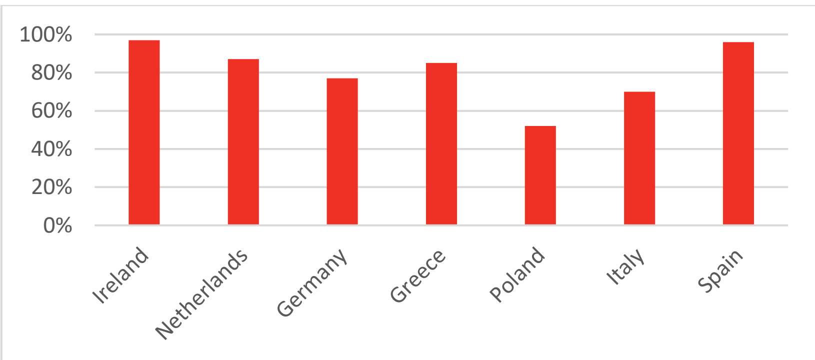
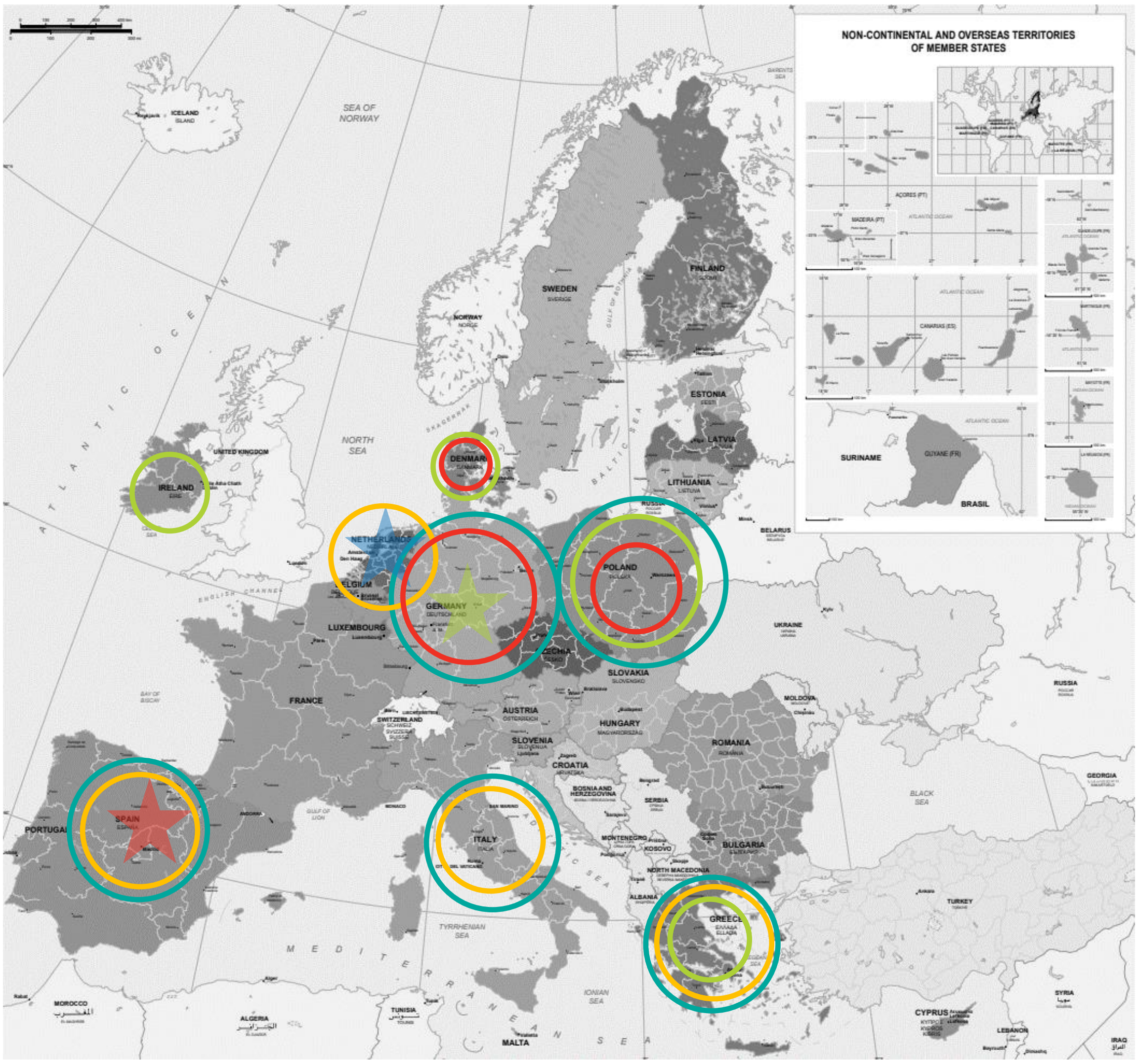


Figure 2-8: Used non-renewable energy in dwellings for space heating per country. (Source: Entranze)



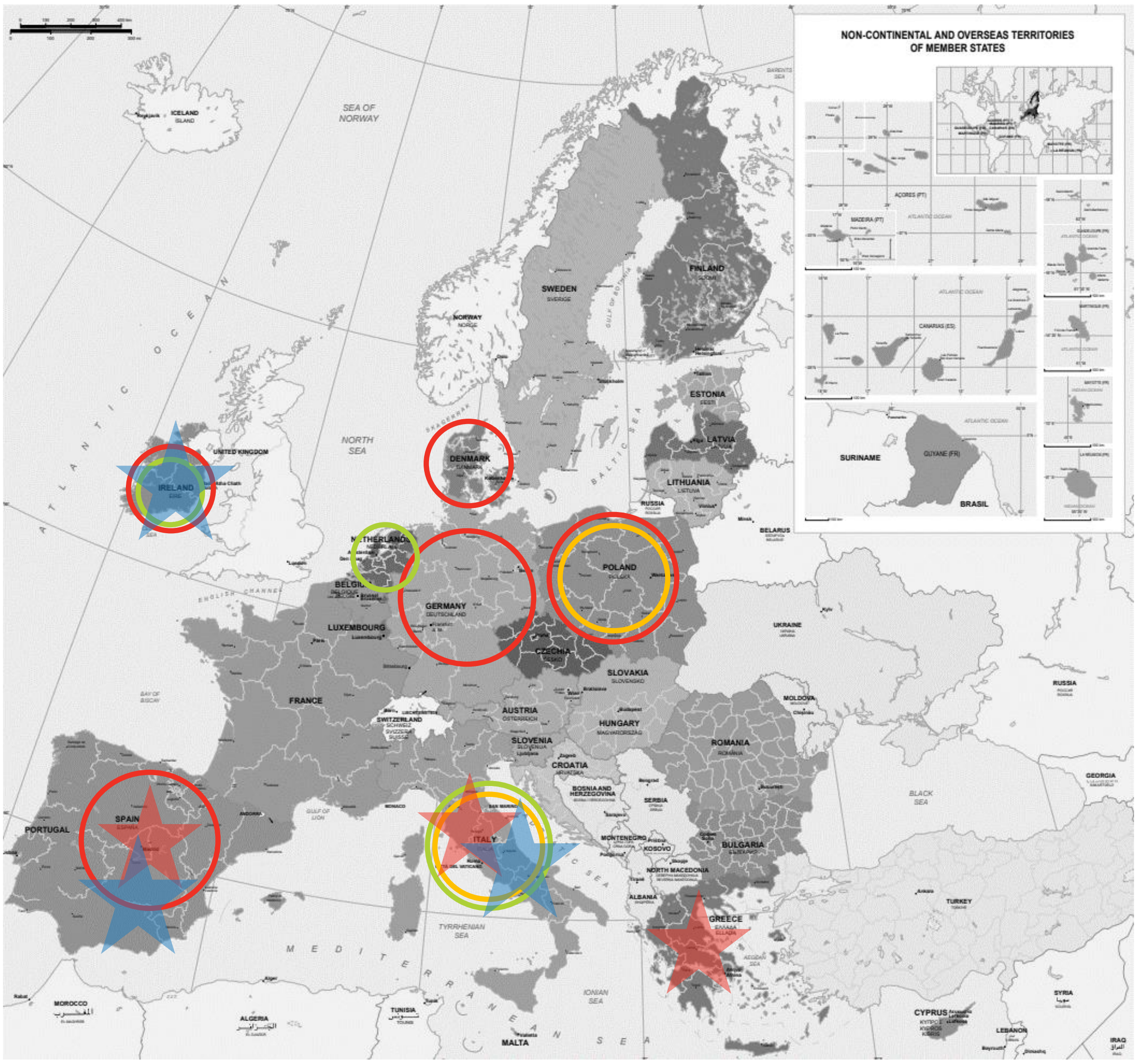
○ (red)	Competition to district heating systems
○ (yellow)	High density areas; large share SFH terraced or MFH's in small areas
○ (light green)	Large shares SFH, in rural areas
○ (teal)	Large shares MFH high energy intensity, in cities and urban cluster
★ (blue)	Highest in social
★ (light green)	Highest in private rent
★ (red)	Highest in owner occupied

Figure 2-9: Indication of possible target locations

2.2.2 Non-residential buildings

2.2.2.1 Share of offices, schools, and healthcare buildings

Denmark, Germany, and Poland have the highest percentage of offices in the total non-residential stock. While Italy and Poland have the highest share of educational buildings, Italy has the highest share of healthcare buildings (EU Building Factsheets).



High share of offices

High share of schools

High share of healthcare buildings

Highest share of energy label C or worse

Highest energy consumption of non-residentials per m^2

2.2.2.2 Energy consumption

According to EU Building Factsheets, energy consumption per m^2 of non-residential building is the highest in Italy, Spain, and Greece respectively which makes them potential target markets for the application of Res4Build system.

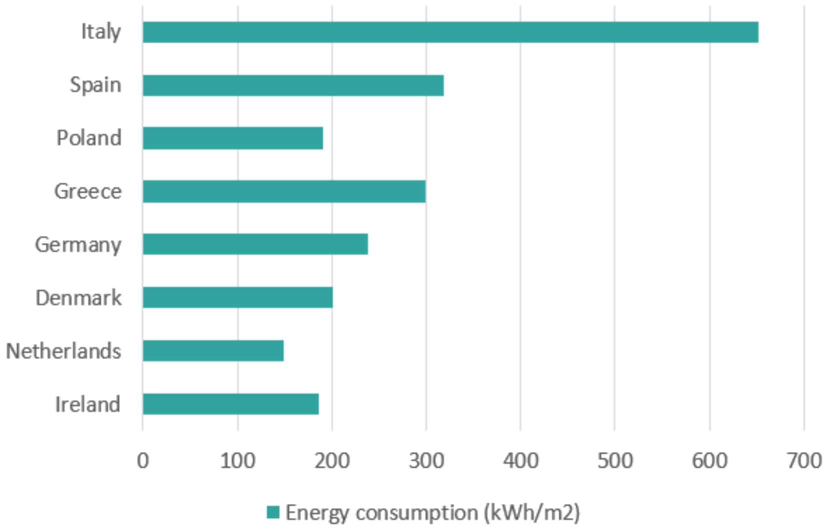


Figure 2-10: Energy consumption per m2 in non-residential in kWh/m2 (normal climate) (Source: EU Building Factsheets, 2013)

2.2.2.3 Energy label distribution

Data on the energy performance certificates of the non-residential buildings was not available for all the countries. From the countries with available data, Denmark and the Netherlands respectively have the highest shares of label B or better.

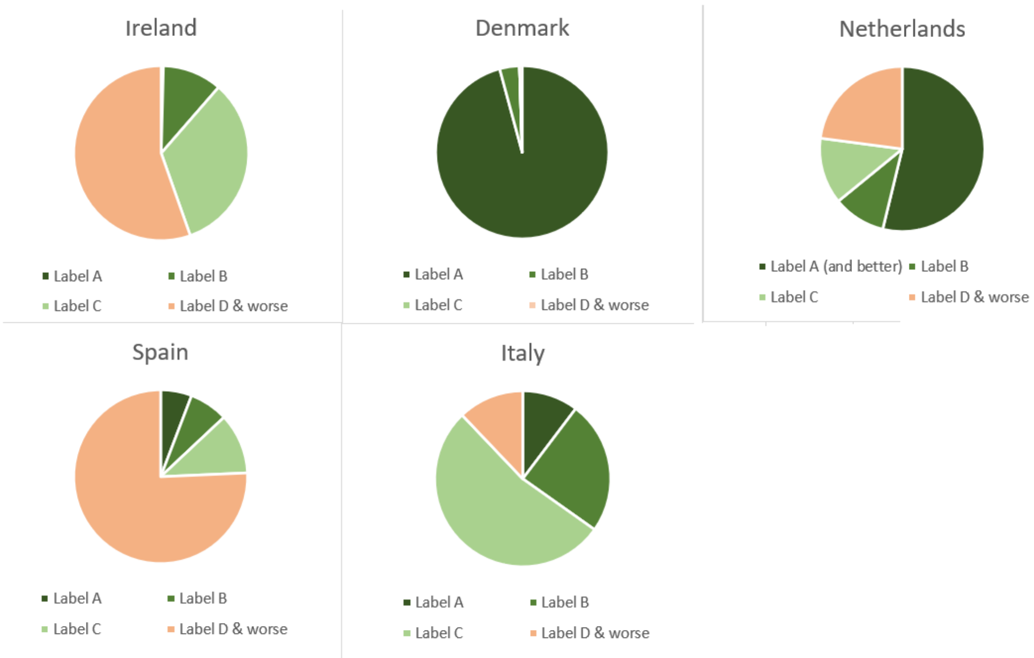


Figure 2-11: Energy label distribution per country

2.3 EU & 8 countries

All country-markets in Europe are directly related to the EU-wide incentives and policies. These are either giving direction or prescribing specific rules. These directions and rules are useable to prepare a ***strategic program of requirements***. This includes requirements for all aspects of the business model.

Each individual country (of which we reviewed 8 in this study), show their own response to the overarching EU-incentives. This is found in the policies and regulations. From there each country defines and organizes their energy market, rules and tariffs. These are based on a mix of cultural, economic and social aspects which drive decision making at government, district, city and individual levels. See below image representing these drivers.

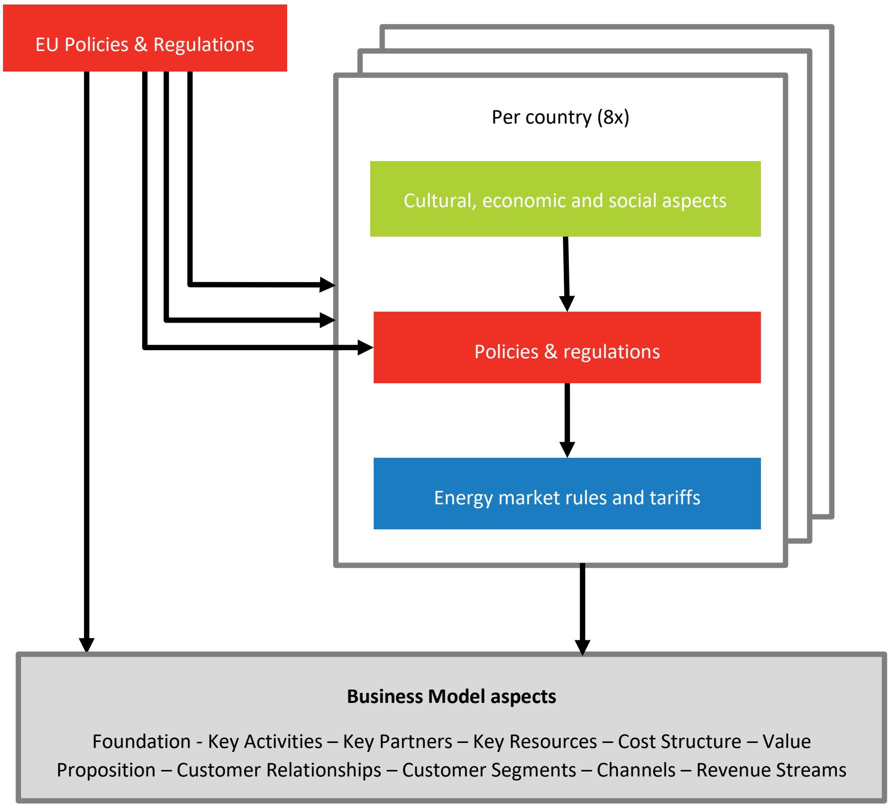


Figure 2-12: Indication of influences between EU & countries

2.3.1 EU policies in the business model

As part of this research, the EU policies & regulations with applicability to the RES4BUILD approach have been reviewed and the requirements are summarized per business model aspect. See appendix L for the overview.

2.3.2 Gap analysis on EU Taxonomy

One specific policy with high impact to the business model is the EU Taxonomy. Therefore, a gap analysis was performed to indicate the level of compliance for the main components in the Integrated Energy System. See appendix M for the gap analysis

2.3.3 Country by country

Per country, the findings on the three aspects (socio-economic, policies, energy market) are summarized in the appendices. The level of details and specific focus on these themes differs slightly between the countries, resulting from the collaboration between various experts and the cultural- or political background of that country.

Drawing short conclusions is a challenge, as the circumstances differ per property sector, income groups, age groups, property ownership and location (e.g. rural / urban). The following table is a high-level summary and should be read as an addition to the detailed conclusions.

The following table shows a very high-level summary of the findings on country-level:

Market	Cultural	Economic	Social	Policies & subsidies	Building Codes	Energy market rules and tariff regimes
Germany	Strong split incentive in residential sector. Much less in offices. Strong economic motives	Reduced capacity for investment	Public sector as a role model	Strict guidelines for subsidies, Renovation measures below optimum	Unified legislations, and regulatory and financial enforcement of EU laws	Incentivized use of electricity and district heating
Greece	New suppliers or technology costs of RES technologies to be a barrier	Energy poverty is an issue while fossil fuel industry is significant job provider.	-	Clear loans and subsidies for public buildings; integrated subsidies for residential (incl. covid recovery). Financial incentives for building envelope and installations	New construction NZEB mandatory	Promoting feed-in premiums
Ire-land	Alternative motives for investment other than energy consumption reduction	Significantly high capital expenditure cost for transitioning to low carbon technology	Existing divide due to the same energy metering systems or split incentive	Promoting rapid build-out of renewable generation capacity, increased storage, and the deployment of zero-emissions gas.	Revised laws to bring Ireland in line with EU	Plans to incorporate renewable energy systems to energy infrastructure by 2030, Time-of-use tariffs,
Italy	New incentives include more bodies as part of energy communities		Lack of overview of initiatives; Energy Communities in small municipalities as a potential to increase RES share in Italy; Many energy communities available.	Need for upwards revised targets of National Integrated Energy and Climate Plan, Gap with the decarboni-zation path, renewables implementation in progress	Complex regulations on different levels: National, regional, municipal	Various tax incentives

Market	Cultural	Economic	Social	Policies & subsidies	Building Codes	Energy market rules and tariff regimes
Nether-lands	Strong financial focus (payback of invest-ments)	Diverse: strong top and low-income groups	Urge for ownership.	Available, but lacking overview	Aligned with EU, but limited ambition	Subsidizing feed-in, while not stimulating storage.
Poland	People in are (increasingly) aware of the benefits of energy system improvement; Building management has been receptive to short term improvements	Increased energy poverty	Energy cooperations with service offerings non-existing.	Weak spots at policy level: SFH subsidies slowing down transition from solid fuels (contradictory subsidies); Lack of overview for MFH's. Addi-tional support for geothermal and energy networks available.	Codes in line with EU, though additional stimuli for upgrade of thermal skins.	Limited financial incentives supporting IES and retrofitting. Feed-in tariffs changing, reducing incentives for e.g. PV. Feed-in tariffs changing: slowing PV implementation.
Spain	Decentralized systems are common and preferred; Large market for BMS and EMS in offices; Limited push for geothermal	Need to combine energy transition & jobs creation; retrofit-ting incentives for residential, offices, and public buildings	Push for more energy communities; Many companies with sustainability certify-cations	Collective self-consumption possible; Lack of regulatory framework for geothermal; Strong CAPEX subsidy framework for RES implementation.	Various frameworks, but lack of dedicated codes for solar and energy storage. Smart meters (elec & gas) mandatory.	Promoting grid feed-in for thermal and electricity; Various options for consumers with self-generation; Use of PV to become mandatory in offices
Denmark	General positive attitude towards the green transition, but "not in my backyard"	Equal grid access and pricing terms for all, community-owned energy supply	Citizen engagement through municipalities or by direct ownership through cooperatives	Subsidies for heat pumps especially outside of areas with available district heating	EN standards for equipment's' performance-related standards	Tariffs vary for the surplus generated electricity

A more comprehensive and useful overview for future business models is given in the appended table, which works as a 'program of requirements' or advised strategies according to the Business Model themes. When using this, the information can be read in line with the EU policies, overlaps can be found between countries and overlapping requirements can be distilled for each part of the business model.

2.3.4 Conclusions

Based on the analysis of stock, EU regulation and market analysis per country a basis is given for development of business models, including priority for the customer segments (market sectors) to target first. This section gives input in predominantly the 'righthand side' of the business model canvas.

The foundation focuses on:

- **Organize collaboration**: define the ownership, partnership, 'collective prosumer' and relations of the property and the surrounding properties in the community and, where needed initiate an organizational form for collaboration on the integrated energy solution.

This may be an energy cooperation, housing cooperation, neighborhood governance or business district. On property level this is mostly defined by ownership, although collaboration with the users (tenants) should be shaped through **'shared incentives'**.

- Follow regional targets for **environmental performance** as a minimum and add national, local or community targets to align with local practice. Adjust the targets over time, e.g. where now focused on 'nearly energy neutral' towards possible 'completely emissions neutral' in the future.

The customer segments to prioritize:

1. Single-family houses (in rural areas) in north-east Europe, e.g. Poland. Focusing on private ownership, low-quality building skin and overall groups which are facing energy poverty. This type of property will be prioritized through EU-regulation and supported. The Polish people show large willingness to support the transition and energy communities are seen as routes to follow, while this market has been underdeveloped. The region is prioritized as the common heating systems are based on coal (both decentralised and district heating) which has high global warming potential and air pollution impact.
2. Multi-family houses in the medium density urban areas in south-east Europe, e.g. Greece. The limited energy performance of this typology, the relatively large share of MFHs, and the dominance of private ownership supports the selection of this sector In Greece. The medium urban area is less feasible for district heating due to less density, therefore IES can be proposed as an alternative. Although the people in Greece show some reluctance to decarbonization, the need is there from the economic situation, with many people having jobs in fossil fuels and therefore energy poverty is a risk. This drawback is expected to be compensated by relatively clear and integrated regulation, combined with policies providing financial support for the transition.
   Office buildings in south-western Europe, e.g. Spain. As a market with one of the highest share of offices in the EU along with the highest energy consumption of non-residential buildings per m2 floor area the potential impact of RES4BUILD system here could be significant.
   In Spain decentralized systems are common and preferred with many interacting system components so a large market for BMS and BEMS in offices. Smart energy meters and installation of PV is set to become mandatory in offices, along with promotion of grid feed-in electricity and thermal tariffs will see minimal storage systems required. IES approach is promoted by the large uptake of sustainability certifications which require 'integrative thinking' amongst offices in Spain.

The client relationship to be based on:

- **Early on** involvement of the customer and local construction partners to integrate ambitions and existing knowledge. Involvement can be found in sharing existing information of the property (comfort, energy use, building quality and components), information on the local market and skills and insight in prognosed changes or desired flexibility. This involvement shall continue during the service offering on the long term, either when systems are delivered 'as a service' or clear instructions for care and maintenance in case of a delivered product.
- Offering on single property and community **scale**: providing both an offering for individuals as the option for expansion to the community as a whole, with system elements per property and the connections to the community.

The channels shall include:

- **Digital** communication structure, fitting the end-product to the targeted end-user, which could be verbal, physical or non-spoken as well to assure maximum inclusion. Data feeding into or resulting from this is to be stored personal files and linked to the property. Maintenance and ownership lie preferably with an organization close to the individual, e.g an energy community. Aggregated anonymous data is to be shared between these communities and network agents.
- **Initial service of retrofitting and installation** works done by local staff, applying elements either from the local market or from the EU region. Supported by e.g. EU-based software and modelling tools which are updated centrally but can be controlled locally.
- **In-use support** by means of a long-term maintenance strategy & building passport. Part of this file shall be the Energy Performance Certificate, which is to be updated with each significant system change that takes place (new build, renovation, upgrade). This support service shall result in updating the thermal performance and/or building services to address challenges over time. Either through exchange of system components, updates of software or settings and instructions for users to optimize performance.
- **End-of-life** strategy where it is clear for the customer how to demount and/or return the system components after use. Also, for the data being shared a policy on storing of data.

The revenues streams are based on:

- A **cost offering** which is acceptable for low-income groups to tackle energy poverty. The acceptable pricing for all is to be achieved by smart combination of monetary schemes. On the income side applying a mix of subsidies, trade of CO_2 emissions and using the prosumer feed-in tariffs. In line with the proposed shared-ownership (e.g. in energy communities), also shares can be given out. Preferable the administrative handling (applying for the subsidies, sales of CO_2 and receiving the fee from feed-in) is to be done by the service company. Aiming to provide continuity (while regulations change) for the end-consumer and assuring that highs- and lows in expenditures will be balanced out over the months or years.

The value proposition shall include:

- For a minimum the installation of smart meters, in addition to any smart control systems.
- Options open for connecting ‘sources’ to the heat pump, either BTES, Air source and/or solar thermal.
- Selection possibility for the heat pump type, either MC, VC or Multi-source.

Overall, the method of analysis sets an example for future business models in the EU-region, in line with the sustainability aims while taking into account local, cultural, economic, energy network and policy aspects. The outcomes are applicable as starting points for future businesses, while it is understood that the specific market analysis for each country will need updating over the years. The sources of information which are used remain relevant though and will guide businesses in the right direction.

3 System analysis

The system components are described in each of the previous deliverables of the RES4BUILD project. They all include valuable lessons and advice for implementing the components, tools or integrating approaches into practice. Opportunities and barriers can be taken out as input for the optimal business models. Additionally, a questionnaire was sent to all project partners, asking them on their thoughts on converting the project elements into a integrated business model. These results are combined with the outcomes of the deliverables. Finally, based on the learnings of the EU-market study, some technologies were high-level reviewed for compliance with the taxonomy requirements. This indicates the ease of adoption in the wider EU-market.

Below is an overview of how each technology relates to the deliverables and the related parties who answered the questionnaire:

System component	Deliverable	Project partner	Reviewed against EU-taxonomy?
Magneto caloric heat pump	2.1 Development and Testing of the Magnetocaloric Heat Pump	DTU	
Multi source heat pump	2.2 Report on the integration of the two heat pump technologies	NCSRD /PSYCTOTHERM	X
PV Thermal (PVT)	3.1 Energy Generation and Storage Technologies – Numerical tool and simulation results	MG Sustainable	X
BTES (controller) - GeoBooster		TerraEnergy	X
Simulation /Grey box models	3.2 Grey-Box Models	VITO; NCSRD	
BEMS and BMS optimization	5.1 Report on the developed and fine-tuned BEMS	ThermoVault and VITO	X
Integrated energy system incl. buffer vessels	4.1 Good Practice of Integrated Energy Systems – On Integrated Energy Systems in the built environment in Poland and The Netherlands 4.2 Integrated Energy Systems (IES) co-design 4.3 Modalities for IES-scaling 5.2 Design of the prototype systems - Preparations of the two prototype systems in Greece and in Denmark 6.1 Technology Factsheets for WLCA 6.2 Integrated Systems Integrated environmental and economic assessment	JIN / BAPE JIN / BAPE JIN / BAPE NCSRD / DTI / Psycotherm Uni of Stuttgart Uni of Stuttgart	

3.1 Magnetocaloric heat pump

3.1.1 Value proposition

There is a need to increase the amount of cost-effective renewable technologies in the property sector for cooling, space heating and hot water. In parallel, stricter rules on refrigerant gasses, which in many cases contribute to the greenhouse effect, are being implemented through the 'F'-Gas regulations. Therefore, the application of a magnetocaloric heat pump (MCHP), which operates by heating or cooling a magnetic material when the applied magnetic field changes, with higher efficiency (and thus higher renewable energy ratio) and environmentally friendly refrigerants (water with some additives) will be valuable.

This value is found in the development of a magneto caloric heat pump, which can be integrated into any existing system configuration, e.g. connected to BTES, PV(T) and / or buffer vessels, or implemented as a standalone solution.

The MCHP is likely to align with the EU-taxonomy requirements, as it makes a substantial contribution to climate mitigation. This is found in the following check on criteria compliance:

Criteria for installation and operation of the MCHP	Characteristics which contribute to compliance (to be assessed in detail, when brought to market).
a) refrigerant threshold: Global Warming Potential does not exceed 675;	The magneto caloric heat pump does not utilize gaseous refrigerants. Also, it has higher efficiency than the conventional heat pumps due to the reversibility of the MCE (magneto caloric effect).
b) energy efficiency requirements laid down in the implementing regulations188 under Directive 2009/125/EC are met.	
c) installation, maintenance, repair, and upgrade of heat pumps contributing to the targets for renewable energy in heat and cool in accordance with Directive (EU) 2018/2001 and the ancillary technical equipment.	To do no significant harm to "Transition to a circular economy", equipment and components of the heat pump must have high durability and recyclability, and be easy to dismantle and refurbish. Also, a waste management plan must be in place which ensures maximal reuse, remanufacturing, or recycling at end of life, including through contractual agreements with waste management partners, reflection in financial projections or official project documentation. This value is achieved by the heat pump being relatively easy to dismantle as it does not make use of a refrigerant. The materials used can be partly recycled after material separation. The return of materials to the material cycle depends on the user. Magnets can be recycled and/ or reused from the developer based on circularity of components within technology development processes from the same or similar developers/institutions for testing and simulation purposes.

3.1.2 Customer segments

Based on research performed by DTU mainly with a focus on performance and efficiency perspectives, the following customer types are identified for the MCHP technology for heating, cooling and domestic hot water applications.

- Residential single family home property with high insulation values (as thermal envelope affects system performance).
    - Other property types (Offices, MFRB, Public Buildings) can use the system, but considering the technology output and technical limitations considerations, alternative options will likely be more suitable to these.
- Small-scale retrofit solutions, where fossil fuel or conventional vapour compression systems need replacement
- Niche markets, where specialized requirements prevent conventional solutions may be applicable but will not be a large share of the market.

The climate zone has limited effect on the performance of the MCHP and therefore is not a barrier to its implementation across Europe

3.1.3 Customer relationships

Introduction to customers has not been researched yet; it is assumed this will be either directly to home or through heat pump suppliers/installers. In order to provide ease of use and installation to the customer, it is assumed that the magneto caloric heat pump will be delivered as part of a service package, as with conventional heat pumps.

3.1.4 Distribution and Resources (Channels)

As a production location has not been defined, the logistic channels are not available. Communication- and sales channels will follow the existing routes as are currently in the market for conventional heat pumps which MCHP is looking to replace.

3.1.5 Key Activities

Installation and commissioning of the heat pump and connecting it to the rest of the (domestic) system. The MCHP must be shown as a reliable replacement for existing fossil fuel systems or high GWP heat pump systems that can be simply installed and operated.

3.1.6 Key resources

Identified key resources for the MCHP include:

- Availability of the relevant materials at a reasonable cost.
- Possibility to couple with other technology, e.g. BTES or vapour compression heat pump
- Development of commercial triangular micro-channels (refer to deliverable D2.1) would allow for a further increase in efficiency of the magnetocaloric heat pump

3.1.7 Key partners

A recognized Magnetocaloric Heat pump representative body or network would be beneficial to its introduction in Europe.

Partnerships with existing heat pump suppliers and perhaps manufacturers to increase technology production and sales would reduce manufacturing and distribution costs

Trusted heat pump installers required for MCHP installation and maintenance for customers.

3.1.8 Costs and revenues

Costs are based on materials, assembly and installation prices which have not been confirmed yet. It is noted that increases in cost of rare earth metals, which are currently mainly sourced from China, would increase the price of the technology.

Revenues will be sourced direct from sales of MCHP and possibly long-term maintenance contracts

3.1.9 Foundation and Further Development

- MCHP has a low TRL 2 which greatly limits its near future market impact.
- MCHP in the future will be a direct competitor to vapour compression heat pump technology in the sense that they have the same function of moving heat from a cold to a hot reservoir.
- The MCHP works best in a cascade multi-source system such as in the RES4BUILD IES where it will work over small temperature differential (2nd stage) to maximise efficiency.
- There are no direct correlations between climate change and the implementation. However, a warmer climate would mean a higher temperature of the cold reservoir, from where the heat is pumped. This would in turn increase the efficiency of the heat pump.
- There is some degree of energy storage built into the technology, as the heat transfer is always through water. This would enable some demand side energy management or frequency response if agglomerated at scale.
- It is expensive, mostly due to the large magnet, which is required.
- The magnetocaloric effect of materials is mostly low which requires further research to improve commercialisation viability
- Solenoid valves have the potential to improve the system performance and reduce the noise level in a MC-HP device compared to mechanical valves
- Microchannel geometry still only at prototype stage and is not yet commercialized

While not currently commercially viable further development is ongoing, and MCHP is changing faster than typical vapour compression heat pump technology and likely to be part of the future energy transition.

- To be taxonomy-aligned, the following activities must be done as the next steps:
    - Accordance with Directive (EU) 2018/2001
    - Energy efficiency requirements laid down in the implementing regulations188 under Directive 2009/125/EC are met.
    - A robust climate risk and vulnerability assessment
    - An Environmental Impact Assessment in accordance with Directive 2011/92/EU of the European Parliament and of the Council, that includes an assessment of the impact on water in accordance with Directive 2000/60/EC

3.2 Multi source heat pump

3.2.1 Value proposition

Heat pump technology for the use of heating and cooling of buildings has existed for decades but has had limited market penetration (for heating) due to the societal reliance on fossil fuels, and the limitations of heat pumps including their single source of energy.

With growing concerns of climate change and global warming, heat pumps are becoming more and more common for homeowners and residents due to their low GWP-refrigerant. Heat pumps provide energy-efficient heating and cooling and are one of the most effective technologies available to decarbonize buildings (driven by reducing carbon intensity of grid-supplied electricity). The flexibility of operation according to the temperature of the heat source to maximize COP makes this product even more attractive to the consumer.

The multi-source heat pump not only has a positive impact on the environment, but also for the user themselves making this one of the most energy efficient products on the market.

Similar to the magnetocaloric heat pump, the multi-source heat pump must make a substantial contribution to climate mitigation and do no significant harm to the other targets to be taxonomy-aligned. The requirements for this are the same as the ones mentioned in 3.1.1.

To do no significant harm to "Transition to a circular economy", the value is achieved through the properties mentioned in 3.1.1. In addition, the refrigerant in the multi-source heat pump has to be directed to incineration due to material mix.

3.2.2 Customer segments

Research carried out by PSYCTO and NCSRD found that the multi-source heat pump would be most suitable for the following resources:

- Building owners
- MEP installation contractors
- Offices (commercial or governmental) – Average 300kW system
- Residential (multi-family apartments) – Average 45kW system
- Public buildings (e.g. civic buildings, educational or cultural buildings) - Average 600kW system

3.2.3 Customer Relationships

One of the key advantages of the multi-source heat pump technology is the manageable maintenance required to run the system. However, like all heating and cooling systems, proper maintenance is key to achieve efficient operation. It is recommended, at least once in 6 months, to clean or replace the air filters. To ensure that the consumer is fully satisfied with the product, regular maintenance checks with a trained heat pump technician will be offered upon purchasing the heat pump. In particular, post-installation monitoring and data analysis is required to 'tune' the MSHP to optimise operational efficiency in differing weather conditions while matching space heating and hot water heating demands. This guarantees a good relationship between the customer and the provider.

3.2.4 Distribution and Resources (Channels)

Distribution and communication and sales channels will follow the existing routes as are currently in the market for conventional heat pumps which multi-source heat pump is looking to replace.

3.2.5 Key Activities

A number of activities need to be carried out to ensure the delivering of a high performing energy efficient multi-source heat pump. These include

- Manufacturing
- Testing
- Installing and commissioning

- Further testing is needed.

Further testing will also be carried out to guarantee optimum performance of machinery.

3.2.6 Key resources

The main resources required to deliver a high performing multi source heat pump are:

- Availability of low GWP and ODP refrigerants for the muti-source heat pumps
- Availability of components based on the sizing that has been designed.
- availability of compressors for the selected low-GWP refrigerant (R454C).
- Tested and proven reliable controls with data archiving and user interface data analytics capabilities

3.2.7 Key partners

The main goal is to obtain partnerships with companies that will expand the client network.

3.2.8 Costs and Revenues

Due to the high quality of this product, the heat pump requires first rate raw materials for both the mechanical and electrical systems.

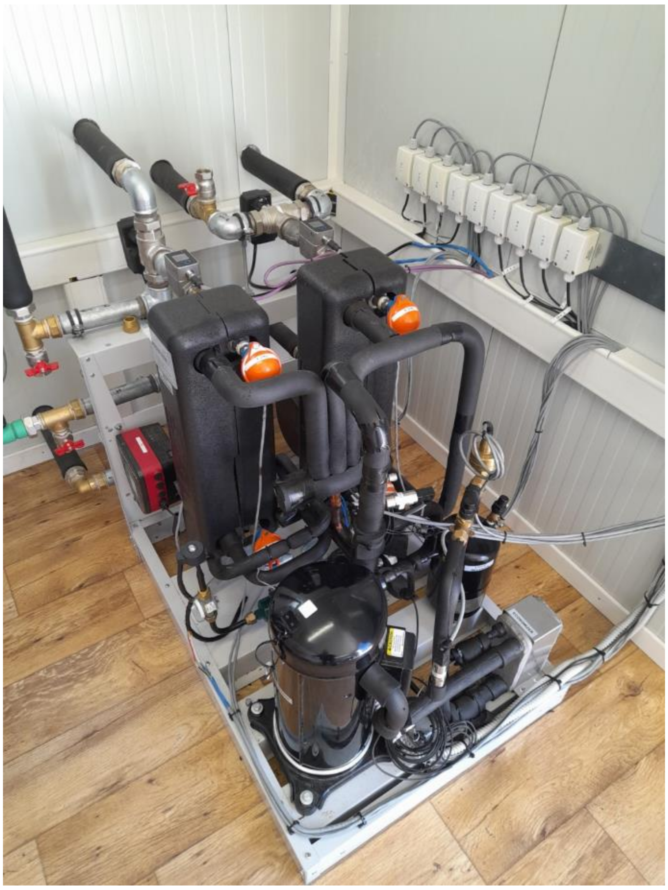
Revenue will be obtained primarily from the sale of the multi-source heat pump to its customers.

The company expects to develop a trustworthy profile with an environmentally friendly reputation while also ensuring the consumer is aware of the economic benefits of the product.

Overtime, these characteristic of the company will increase the sales and revenue.

3.2.9 Foundation and Further Development

Although there are a vast range of advantages to the multi-source heat pump, a number of technical barriers with the multi-source heat pump must be overcome before implementation. Currently the system is at TRL 5, meaning the technology is validated in the relevant environment, which is an on-going process during the pilot testing in Greece and in Denmark (the figure below shows the installed prototype in the Greek pilot system). This low TRL poses limitations for the foundation and further development of each the products.



The availability of a compressor with economizer for R454C poses a problem. This piece of equipment is required to make sure that the heat pump is operating at highest efficiency. Withing the last year, some manufacturers have started to produce the compressors for R454C but have yet to fabricate a version with the economizer port. At the moment, this causes limitations of the multi-source heat pump and requires further development. However, even with the absence of the economizer option, the solution can move forward, but having a lower performance at heating mode, similar to standard heat pumps. To make full use of the multi-source option, an efficient control system is required to optimize the operation and performance. The PLC-based control of the heat pump relies on a rule-based control that has been developed according to best practice principles derived from the testing period. Therefore, the BEMS control with optimization features is needed to exploit its full potential. This must be trialed and tested before the heat pump can be ready for market.

A well dimensioned system can lead to significant operation cost savings, but the components estimation and selection needs to be precise. Furthermore, the right control/operation strategy must be determined, leading to the selection of the appropriate heat source and leads.

An adaptable in-depth analysis system needs to be established as there are a number of components which will vary depending on the requirements of each consumer. For example, a residential unit will not require the same multi source heat pump as would a commercial office building. Another option that differentiates the design is whether the cycle will be reversed for enabling the cooling option, which depends on the application and the climatic conditions.

3.3 PV Thermal

3.3.1 Value Proposition

Photovoltaic thermal collectors are power generated technologies that convert solar radiation into thermal and electrical energy. PV thermal collectors benefit the environment, while lowering the overall energy costs of a building. There are a number of advantages of the PV thermal outlined by Hogskolan I Gavle (HIG) and MG Sustainable Engineering (MG SUSTAINABLE ENGINEERING AB) that are explained in further detail below.

PVT also promotes heat electrification by both reducing thermal energy demand by providing a passive source of thermal energy, and also producing green electricity for use. Unlike fossil fuels such as coal and natural gas, PVT does not release harmful pollutants or greenhouse gas emissions like carbon dioxide into the air This reduces overall carbon footprint of the building and makes it a reliable source of renewable energy.

Home solar PVT, coupled with battery storage, can offer homeowners freedom from utility companies with high electricity bills. The installation and use of PV thermal appliances avoid peak electricity rates and provides reliable back-up power and hot water when the grid goes down.

These characteristics highlight the main value proposition of this product and both its financial and environmental benefits. PV thermal product can reduce electricity bills and provide hot water from the one component increasing the renewable energy production density and reducing the space requirement.

As part of the taxonomy compliance, the PV thermal obtains the value of not doing a significant harm to “Transition to a circular economy” through the following aspects:

- Geometry gives higher material durability due to a more uniform radiation distribution profile.
- The materials used can be partly recycled after material separation. The return of materials to the material cycle depends on the user.
- Glass in the PVT collector can be partially recycled and partially sent to landfill. Solar (PV) cells can be sent to landfill.
- Thermal utilization is possible for plastic parts, while all components can nevertheless be directed to landfill.
- The designed geometry allows for ease of installation.
- Target lifespan for the silicon encapsulation of solar cells is minimum 25 years and withstands high temperatures.

3.3.2 Customer Segments

Buildings are the main consumers of energy. Therefore, the main customers for the PVT are:

- Offices (commercial or government, including mixed-use)
- Residential (single-family house)
- Residential (multi-family apartments)
- Public buildings (e.g. civic buildings, educational or cultural buildings)

Targeting these above sectors, particularly those with limited open roof space such as residential will maximize the fossil fuel reduction capability of the system.

Furthermore, PV thermal could also be installed for any customer that has a low temperature heat demand while producing useful electricity production.

3.3.3 Customer Relationships

Building a working relationship with customers is key to achieve long-term success of a business. Having a strong connection based on trust and communication helps customers feel more secure and connected with the product, and it can also lead to growing customer retention and repeat purchase rate of the PVT.

When compared to other systems, PVT have relatively low maintenance, but a good relationship is important to ensure good communication between the supplier and consumer. It is important to highlight to the consumer the benefits of investing in a PVT. A crucial aspect of a PVT is that it reduces a buildings carbon consumption while also reducing energy bills. Although the initial payment for the PVT is expensive when compared to other sources of energy, with time the consumer will save money on energy bills.

PV thermal presents the solution that tackles decarbonization of buildings while also tackling the cost of high electricity bills.

3.3.4 Distribution and Resources (Channels)

The main methods of distribution for PV thermal are logistic channels (distribution of goods), communication channels (distribution of information) and sales channels (web shops; shops; sales portals).

3.3.5 Key Activities

Developing resources and partners as outlined below is necessary for the success of the PVT product.

With a rechargeable home solar and battery system, the cost to generate electricity is at a steady rate, meaning that energy bills are consistent and rarely fluctuate in cost. Home solar panels offer freedom from utility companies with high electricity bills.

By using solar energy, which often coincides with peak demand in commercial and public applications, this avoids the most expensive time of use rates, while further optimizing energy savings.

This can also lower the peak for utility companies to reduce overall grid costs by not requiring expensive ‘peaking’ electricity production.

3.3.6 Key Resources

They key resources for the PV thermal are

- Installers
- System designers
- Sales personnel
- Production Team

All these are required to deliver the highest quality product.

3.3.7 Key Partners

The main key partners are energy producers or retailers. Forming relationships with renowned PVT distributors and installers worldwide ensures rapid dissemination of the product. These distribution partners hold, market and sell stock in their locations all across the globe. Creating this partnership with energy retailers will have a positive impact on the business’ relationship with customers and build a sense of trust between the consumer and distributor. Thus, promoting sales and profitability of the product.

3.3.8 Costs and Revenues

The cost structure is the funding that provides for the development, delivery and operations of the value proposition in the business.

The system components are an important initial cost. The collector is the heart of the system; however, the system will not work without the remaining components in the system. It is important to invest time and money into a high-quality collector to ensure the PV thermal works at high efficiency. On average, the collector will account for about 30% of the total cost of the installed system while labour and other system equipment will account for the remaining 70%.

Quality of installers is another important cost of the system. It is important that the PV thermals are installed correctly in each building, so they work effectively and efficiently. As previously stated, consumer relationships are very important to ensure profitability of the products. One of the most enticing aspects of PV thermals is its high-quality performance and low maintenance costs so it is important to ensure the system is installed correctly so the consumer can benefit from it. With high quality products, this will guarantee customers will remain loyal to the products and the business will continue to grow over time.

3.3.9 Foundations and Further Developments

These environmental and financial benefits make the PV thermal a desirable source of energy for consumers. There are a number of constraints with both products that limit the readiness of the PV Thermal products. HIG's product is at TRL8 meaning that the system prototype demonstration is at an operational environment. While MG Sustainable Engineering's system is complete and qualified. However, both products require a lot more testing and research before they can be sold to consumers.

Before the PVT is ready to go to market, the testing of the materials used in the system is required. It is important that PVT undergoes short outdoor testing to ensure that the materials are capable of adapting to different climates and weather changes. The PVT needs to be affordable, yet good quality.

PVT requires a level of certification. At present, certification for design is either photovoltaic or thermal but has not been established for PVT. PVT needs to prove itself in the market in order to ensure that it gets included in the wider offer of subsidies and certifications for example.

To be taxonomy-aligned, the following activities must be done as the next steps:

- Accordance with the statistical classification of economic activities established by Regulation (EC) No 1893/2006 must be assessed
- A robust climate risk and vulnerability assessment
- An Environmental Impact Assessment in accordance with Directive 2011/92/EU of the European Parliament and of the Council, that includes an assessment of the impact on water in accordance with Directive 2000/60/EC

3.4 Borehole Thermal Energy Storage system – Controller

3.4.1 Value Proposition

A borehole thermal energy storage (BTES) system is an underground structure for storing large quantities of heat collected in summer for use later in winter or vice versa for coolth in summer. There are a number of advantages associated with the borehole thermal energy storage system. The installation of this system will decrease the overall carbon emissions while also lowering overall cost of the building. BTES systems need only a relatively small amount of horizontal space to tap into a large volume of subsurface rock provided the geology and drilling capability is suitable. This can give BTES a space saving advantage over other storage technologies like water tanks, particularly in densely populated urban areas. This main advantage of this system that will be highlighted to consumers is that it is aimed to have long term performance and security of heat/cold supply for the buildings in question.

A challenge with these BTES systems is that they do not always use the available energy in an optimal way. In a conventional setup there is no follow-up on the actual state of the BTES field which can lead to thermal depletion of the BTES. The BTES controller is developed to tackle this risk. The controller guarantees the output power (kW) of the BTES field while safeguarding the annual energy production (MWh) for heating and cooling so that no extra installation investments are needed. The controller calculates the required extraction or injection rate at any time, taking into account the heating and cooling energy that needs to be delivered later during the remaining heating/cooling season. This strategy enables an active anticipation in order to avoid geothermal exhaustion. For bivalent systems, consisting of a BTES and a backup installation, the optimal switching point for the peak boilers or chillers is also determined. Furthermore, the BTES controller can also be used to help adequately size a BTES even including installation a backup peak installation. By doing this, the peak installation can be minimized which will reduce the installation cost

3.4.2 Customer Segments

This system is highly compatible for:

- Offices (commercial or governmental, including mixed-use)
- Residential (Multi-family apartments)
- Public buildings (e.g. civic buildings, educational or cultural buildings)

It is expected to reach these customers through a 3rd party such as an equipment supplier, contractor, or Energy service company (ESCOs).

3.4.3 Customer Relationships

In order to sustain the productivity and efficiency of this system, service packages and regular updates are mandatory for this solution. This will ensure that the system is performing at high efficiency, lowering carbon emissions and electricity bills. This will guarantee a good customer relationship will be sustained as the benefits of this system will be apparent to the consumer.

3.4.4 Distribution and Resources (Channels)

The BTES systems as an energy storage device will likely need to operate in conjunction with a separate heating and/or cooling system such as a heat pump for typical operation. Therefore, distribution and communication channels will likely be coupled with large scale heating and cooling system providers, along with thermal energy storage system providers. Direct communication and distribution with Energy service companies (ESCOs) will also be a target market.

3.4.5 Key Activities

The main activities required for this system are

- Development of market geology and drilling skills and regulation for the implementation of suitable boreholes
- Working with Energy service companies (ESCOs) to develop BTES as part of service offerings
- Installing extra measurement equipment (if not available) for thermal storage optimisation
- Deploying the solution so it can read out measurements from the installation and send control signals to the installation

3.4.6 Key Resources

The key resources required to deliver the value proposition are

- Proficient geology and drilling expertise, practitioners and regulation for the implementation of suitable boreholes
- Availability of required monitoring/measurement equipment
- Skilled people to install the complete workflow from reading in the measurements, calculating the optimal control to applying the control signal on the system

3.4.7 Key Partners

Key Partners are essential relationships that assist the business, and ensure the business model will work. The BTES Booster has to be integrated into a complete offer. This means it is important to partner with full system providers to ensure the consumer will receive a complete system. These pure player business' will provide BMS integration and BMS manufacturing of the system.

An important partner will be the energy service companies. Energy service companies (ESCOs) develop, design, build, and arrange financing for projects that save energy, reduce energy costs, and decrease operations and maintenance costs at their customers' facilities. In general, ESCOs act as project developers for a comprehensive range of energy conservation measures (ECMs) and assume the technical and performance risks associated with a project. Therefore, ESCOs are important in ensuring a good relationship between the company and the consumer.

3.4.8 Costs and Revenues

The most costs significant in this solution are

- Costs for developing the BTES controller software
- Costs for deploying the BTES controller software in the field
- Limited costs for adding extra measurement equipment if necessary

Revenue will be collected through sale of the BTES system, licensing of the controller and service or maintenance agreements.

3.4.9 Foundations and Further Developments

The technology readiness level of this system is quite low, at TRL3. This means that the proof of concept has been established, however no testing or validation has been carried out. The technology requires a lot more development before it can be used by consumers.

Despite their high specific heat capacity, hot water tanks require a considerable amount of space, and thus, are typically used for short-term heat storage only. On the contrary, closed-loop geothermal systems are inherently suitable for sensible heat storage in densely populated urban areas. Closely-spaced BHE arrays can be operated as BTES systems and provide capacities sufficient for seasonal heat storage with a much lower space requirement compared to hot water tanks with matching capacities.

The solution is only relevant in large projects where backup units can take over the demand of the BTES. Currently most BTES installations are built without backup installations. This poses a problem for implementation of the system due to the small serviceable available market and with getting access to the right measurements of existing installation.

The separation of players (BMS integration, BMS manufacturing, BTES Design) makes adoption of the solution more complex. Due to the system requiring a variety of different services provided by pure player businesses, it is important to establish the needs from each supplier. It is important to communicate and co-operate with each of these businesses to ensure the manufacturing of the product runs smoothly and efficiently.

Due to the lack of maturity in the field, this means it is difficult to deem the added value of the controller in the system. This is important to know as it determines the importance of the controller in the system. The controller has a number of benefits; however, it is important to establish a cost price to see it is affordable.

The following future steps must be taken to become taxonomy-aligned:

- Accordance with Article 10(1), point (i), of Regulation (EU) 2020/852 where it complies with the technical screening criteria must be assessed.
- A climate risk and vulnerability assessment
- An Environmental Impact Assessment (EIA) or screening in accordance with Directive 2011/92/EU334

3.5 System Simulation Platform

3.5.1 Value Proposition

The system simulation platform is a combination of system component simulation softwares and building models used to identify the most suitable sizing of system components (e.g. heat pump capacity, tanks volume) to ensure that the estimated heating/cooling demand is covered. This can lead to cost reduction by not oversizing some components and will also reduce energy usage and electricity bills.

Often dimensioning a HVAC installation of a building including buffer tanks and optionally seasonal storage is a challenging task. By executing some simulations with different types and dimensions of the installation, an optimal choice can be made without having to over-dimension the system. Therefore, an easy-to-use simulation framework is needed. Once the HVAC installation is installed and commissioned, it can only be used in an optimal way by integrating a smart controller into the BEMS of the building. The optimization framework developed in RES4BUILD uses an implementation that can be used both for simulations and real-time control.

The main advantage of the optimization framework is its ability to adapt its configuration for new models of buildings or equipment, meaning it is usable for simulation and optimization of different system setups.

Research, design, and technology organizations benefit greatly from this software as the models can improve the efficiency of working applications using the thermal flexibility of buildings. The models are readily available and can be used 'out of the box' by feeding in measurements or sample data from the building to train the model. Once the model is trained, it can be easily integrated into any application.

Furthermore, optimization framework makes this system more attractive for consumers. Scientists and research and technology organizations will be able to use the framework to carry out optimizations and simulations or use it for real-time control in labs or pilots. ESCOs/Energy suppliers can use the framework for carrying out optimal building control in the buildings of their clients, minimizing the energy cost and maximizing the self-consumption. Building owners can use the framework to integrate the optimal control into the future BEMS of their building.

The main attractive advantages of the solution are:

- Component database to include or exclude several components
- Some component models have been validated based on the available tests (e.g. PVT, heat pump)
- Source code developed by VITO and NCSRD and is available for future change/improvements

3.5.2 Customer Segments

This system is highly compatible for:

- Offices (commercial or governmental, including mixed-use)
- Residential (single-family house)
- Residential (multi-family apartments)
- Public buildings (e.g. civic buildings, educational or cultural buildings)

There may be further interest for design and optimisation of platform for:

- Scientists and research and technology organisations
- Electricity market players/DSOs
- Energy Service Companies (ESCO)
- District Heating System owners

3.5.3 Customer relationships

To guarantee a good relationship with the consumers, there should be an option to provide regular updates to enable new features or fix bugs. This ensures that the system is working effectively and efficiently and will maintain a positive alliance with the consumers due to the longevity of the system.

Electricity market players can use the models to aggregate the total thermal flexibility in their portfolio and transform it into electrical flexibility that they can then use to bid on the electricity market or to balance their portfolio.

District Heating System owners can use the models to aggregate the total thermal flexibility of the buildings connected to their network. Based on this they can use it for applying different objectives on the network, e.g. reduction of heat losses, optimization of the central production plant and peak shaving of electricity demand, while maintaining the end user's comfort by keeping the indoor temperature between a predefined lower and upper boundary.

3.5.4 Distribution and Resources (Channels)

The main method of distribution is to license the simulation platform or to provide a consulting service approach. The distribution channels will likely be coupled with heating and cooling system providers, along with typical building energy management system providers for the optimisation element.

The company communicates and reaches customer segments to deliver the value proposition through:

- Communication channels (distribution of information)
- Sales channels (web shops; shops; sales portals)
- Technology transfer

3.5.5 Key Activities

The main activities that are required to ensure the company operates successfully are guiding the deployment process of the software at the customer and testing if the solution works. As previously stated, this maintains a good relationship between the company and the consumer.

3.5.6 Key Resources

It is important that people with the necessary skills and experience are appointed to operate and install the solution. This is a key resource as the skills and capacity of people are required to understand the building modelling and optimization framework to extend the solution with new features and to do a technology transfer to interested customers if desired.

3.5.7 Key Partners

The key partners for this software are a research institute (e.g. VITO). An affiliation with a system integrator is needed as the research institute will not be able to provide permanent support 24/7.

3.5.8 Costs and Revenues

The main costs for this system are:

- Development (highest cost)
- Training of the people that have to work with the solution
- Recurring costs of support and updates with new features

3.5.9 Foundations and Further Developments

There are a number of constraints regarding this solution which can be attributed to the low technology readiness level. Currently, the solution has only been validated in the lab and has not been tested by consumers yet. This causes limitations and barriers for the system.

At present the solution is not user-friendly. The initial simulation tool has been written in Engineering Equation Solver (EES) environment, which aims in finalizing the code in a short time, and then used for parametric studies. This tool has limitations in the number of equations (and subsequently in the number of different components) and time-steps that can be simulated.

Furthermore, once the system is in place, external software is needed to prepare in tables the weather data and building demand (from an in-house Python code or any other source). Therefore, further developments are required that may integrate some smart-control features instead of rule-based control that is currently implemented.

The model identification for the grey-box models, a core element of the simulation system, is considerably complex. Although the models are linear in states and inputs, the problem of parameter identification is highly non-linear and is prone to many local minima.

3.6 BEMS and BMS optimization

3.6.1 Value Proposition

The Building Energy Management System (BEMS) and optimization solution will allow the user to operate their energy system as designed, enable accurate commissioning and on-going monitoring of performance which can be optimised based on collected data and developed optimisation algorithms.

The main attractive advantages of the solution are:

- Portable to different building types
- Low cost in comparison to commercial offerings for larger buildings
- Offers advanced control also for smaller buildings

3.6.2 Customer Segments

The BEMS and optimization solution is highly compatible to the following customers;

- Offices (commercial or governmental, including mixed-use)
- Residential (single-family house)
- Residential (multi-family apartments)
- Public buildings (e.g. civic buildings, educational or cultural buildings)
- Early adopters, building owners, installation contractors, cooperations, energy companies (resale), device vendors (bundled).
- Engineering firms (probably small ones) that have limited access to commercial software and are willing to provide custom-made solutions to their clients.

3.6.3 Customer Relationships

Customer relationships will remain positive by providing assistance for the installation of new components and the placement of old components. There must be a constant communication with the customer as there needs to be regular updates to the account for changes in tariff structure. Other heating technologies may become available or become popular (e.g. auxiliary heating with hydrogen or biofuels) and it is important for the consumer to have the latest technology. Post installation data archival and analytics support is needed to verify optimized plant operation is achieved.

3.6.4 Distribution and Resources (Channels)

The distribution and communication channels will likely be coupled with heating and cooling system providers, along with typical building management system providers.

3.6.5 Key Activities

The necessary activities for this solution are to

- install and configure the system, including inputting the necessary data for the building/buildings in question
- educate users on the proper use of the system
- The upkeep of energy system changes which will affect cost structure
- Development of simple graphical user interface to show current and historical systems operation and performance.

3.6.6 Key Resources

The main resources required for this solution are

- predictable user behaviour
- suitable instrumentation and data in buildings
- standardized controllable devices

3.6.7 Key Partners

The key partnerships that are required to get the value proposition to market are:

- vendors of energy components
- energy system integrators
- Trained installers

3.6.8 Costs and Revenues

For the BEMS, there are a variety of expenses throughout the installment of the solution. Firstly, the cost is in up-front hardware and software development cost. During operation there is cloud/communication cost, and cost to keep the system compatible with upcoming standards. To maintain the systems efficiency and effectiveness the software requires regular checks and maintenance so there will be a further cost for personnel to improve the software and apply it to the solution.

3.6.9 Foundations and Further Developments

The main constraint of this system is that is not sufficiently developed for full commercial use (TRL5). The solution requires a lot of data and information input and without this, there are a lot of assumptions that must be made, meaning that the results can be inaccurate.

Inside the household or small business, it is difficult to obtain information on tariff information, at this moment it needs to be tailored for each installation. Access to (smart) meter data is different per country and may be subject to administrative processes. In-household communication between devices is challenging and the tariff structure influences the optimization problem More granular controllable devices may be needed to maximise energy and carbon savings depending on the precise terms and conditions of the tariff structure (e.g. control over the modulation of a heat pump).

Furthermore, simulation technology is at the heart of this solution. For that reason, hardware and software reliability is a key factor for this system. For this reliability of the energy systems themselves, cloud operating costs, device interoperability, specification/configuration of energy systems, enterprise network configuration, network connectivity, component sourcing.

To obtain value proposition for the taxonomy compliance, the following future steps must be taken:

- Compliance with the technical screening criteria set out in Article 10(1), point (i), of Regulation (EU) 2020/852 must be assessed.
- A robust climate risk and vulnerability assessment must be performed.

3.7 Integrated Energy System Delivery Framework

3.7.1 Value proposition

The IES co-design service allows for the involvement of one company/entity dealing with different technologies, engineering solutions, providing energy, design and financial consulting. It simplifies the entire investment process for the customer and in the future may help to create a ranking system of co-design service providers. This will bring more trust/safety to the market causing higher interest in such solutions leading to faster and increased development of such projects.

The IES modalities framework (see Figure X) allows both end-users / building owners (demand-side) and IES providers (supply-side) to respectively host a participatory process (co-design) to determine what services should be provided by third parties, and to develop an IES service supply business model that can meet the needs of different end-user groups. The IES modalities framework challenges end-users / building owners to reflect on which capabilities and resources they already have available in-house, and what technical, financial and organisational expertise needs to be provided by (in)dependent third parties. For IES providers the modalities framework challenges them to reflect on which combination of IES services can or should be provided to the different end-users groups within different sectors.

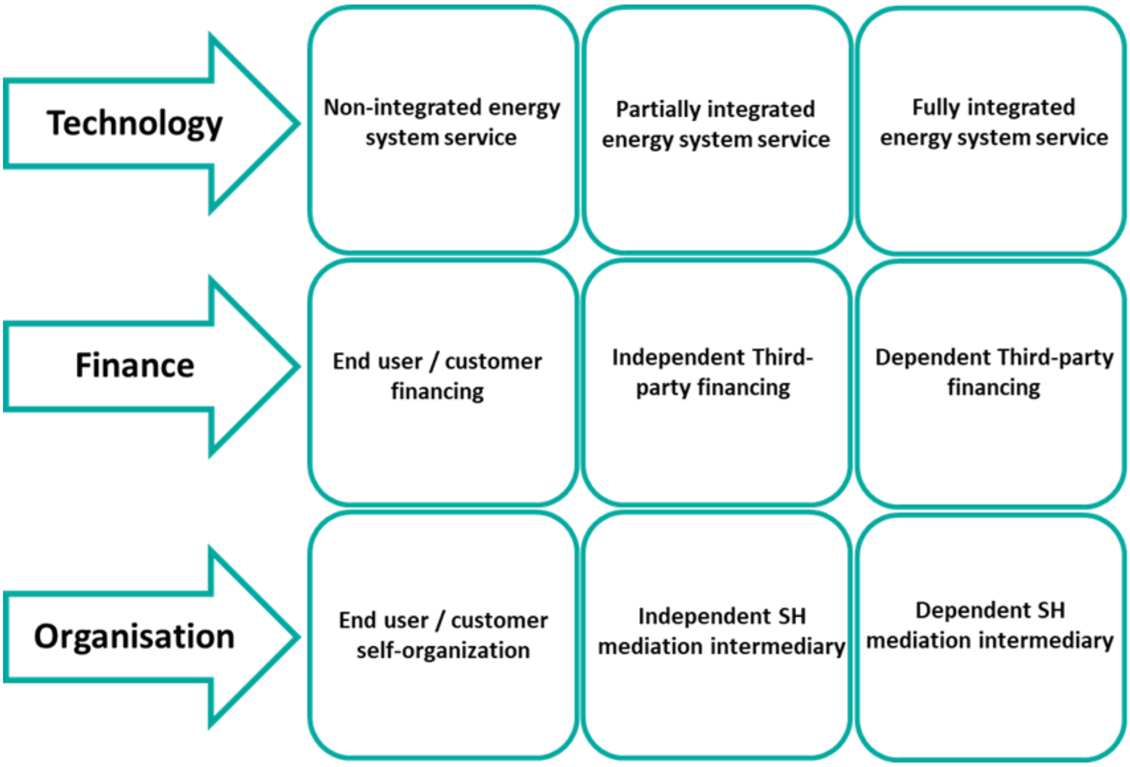


Figure 3-1: Different technological, financial, and social-organisational modalities for IES co-design (JIN, Deliverable 4.3 RES4BUILD Project, 2022)

Within a subsegment of the built environment (e.g., health care) where the building management is run by trained professionals in asset management the type of IES service level provided could target only on providing standardized, integrated technology packages. In another context, such as multi-family residential buildings, the type of service level could include not only provision of an integrated technology package, but also a suite of funding/financing options (e.g., rent, lease, buy), or performance contracts as well as additional services for organising, moderating the participatory decision-making process and/or any engagement / communication processes before, during and after IES implementation. The IES value proposition can (and should) be tailored to the specific needs of the end-user groups within the subsegment of the built environment (e.g., public real estate, commercial real estate, multi-family residential buildings, health care real estate, etc.).

3.7.2 Customer segments

This concept's main customers would be:

- Technology / component suppliers,
- ESCo's
- Building and construction companies,
- Installers
- End-users/investors

3.7.3 Customer relations

To guarantee a good relationship with customers, there must be constant communication between the service provider and the consumer. Each customer has different requirements for their system and therefore it is important to make each system specific to meet the consumers' needs. Common meetings, workshops and decision-making processes would aid with determining which supporting services are needed for effective implementation of energy saving technologies and practices within buildings. These workshops/meetings can also be used by stakeholder groups to discuss and decide which activities they will perform themselves, and for which activities / services they require additional (external) support, knowledge, and expertise. These meetings would not only help in building mutual trust between consumer and supplier, but also facilitate the decision-making process for stakeholders.

3.7.4 Distribution and Resources (Channels)

The main form of distribution of this service would be;

- Communication channels (distribution of information)
- Sales channels (webshops; shops; sales portals)
- Trainings, workshops, conferences, one-stop-shops

3.7.5 Key activities

To ensure that the concept is used and each system performs as effectively and efficiently as possible, there are a number of key steps required. In order to improve the quality of the technical solution, engaging people in the planning process from the very beginning of a building renovation project, where joint existence of multiple energy technologies is replaced with an integrated solution.

Integrated actions, such as households sharing a building block or living in one district with comparable dwellings, united by an owners' or housing association, can improve the quality and/or lower the costs of the IES solution applied.

The IES Good practice assessment (see Spijker E., et al., 2020) identified key success factors for IES implementation, which should involve not only the provision of an integrated package of energy saving and renewable energy technologies (IES), but also provision of suitable financing services as well as social-organisational services for end-users / building owners to better inform and manage complex multi-stakeholder decision-making processes.

Furthermore, there must be testing, commissioning and maintenance of the solution to ensure it is at optimal performance.

3.7.6 Key Resources

It is important to involve the right (community) of stakeholders that can all contribute with their own skills-sets and capabilities to co-design to offer a comprehensive IES co-design service. This is crucial for the successful implementation of the concept. IES modalities framework (see Spijker, Gaast, Wach, K.Grecka, & Szajner, 2022) that allows end-users / building owners to self-diagnose which technological, financial and social-organisational activities and services they would like (or are capable) to perform themselves, and which IES services would best be outsourced (see Figure 3-1). At the same time the IES modalities framework also provides a reference framework for IES suppliers to design their service level and value proposition.

3.7.7 Key Partners

This co-design service may require partnerships of suppliers of individual technologies (PV, heat pumps, heating installations, insulation), as well as technical consultants, designers and installers. it requires tight cooperation with different types of stakeholders and building mutual trust. See Spijker, Gaast, Wach, K.Grecka, & Szajner, 2022 for a more detailed discussion on stakeholder network mapping and management.

3.7.8 Costs and Revenues

In addition to typical investment costs, there may also be costs of workshops, promotional campaigns, organization of meetings with stakeholders, cooperation with suppliers of individual technologies. The co-design service contributes to raising awareness on climate problems. Solutions proposed should lead to energy costs reduction and implementation of innovative technologies.

3.7.9 Foundation and Further developments

There are some limitations with the IES concept. The service is not wholly standardized at present, although this is being progressed and there are several suppliers of IES services. However, a more standardised process taking account of RES4BUILD learnings should be implemented to achieve greater market penetration.

There are also a number of aspects of this concept that may limit consumers adaptation to this approach. People are asked to give up an existing situation that they are used to and to do so they demand at least an equivalent energy service in return, if not better. The energy needs to be affordable so that the net costs of IES systems and the energy bills paid by the consumer over time do not vary greatly when compared with their old system. IES combines and balances different energy services in a building, it is important to know exactly what the consumers key requirements of this concept are in terms of energy supply which is shown in RES4BUILD deliverable 4.3. This is even more important in case of multi-purpose buildings with different users, with different needs and perhaps at different moments of the day.

4 System design and Operational Performance

4.1 System design

Based on the detailed markets and system analysis as summarised above the target markets for each of the RES4BUILD technologies are identified. These markets are selected as the locations where the technology is expected to have the greatest impact and likelihood of success. Combining the most suitable technologies for each country (representing a target market climate/location) the proposed adapted RES4BUILD system applicable to each market is presented as outlined below.

It is noted that based on system and market analysis, it has been found that IES methodology, simulation platform and BEMS optimization software are the most versatile concepts which can be used in all countries that have participated in this review.

4.1.1 Magneto caloric heat pump

The magneto caloric heat pump operates by heating or cooling a magnetic material when the applied magnetic field changes. The magneto caloric heat pump can be integrated into any existing system configuration or implemented as a standalone solution. Based on the system and market analysis, Denmark have been selected as a suitable user of the magneto caloric heat pump.

System component	Ireland	Netherlands	Germany	Poland	Italy	Spain	Greece	Denmark
Magneto caloric heat pump	-	-	-	-	-	-	-	+/-

MCHP has a low TRL 2 which greatly limits its near future market impact. Due to the low technology readiness level of this product, it is difficult to determine some key aspects regarding the operation of this concept and hence its applicability on the market. It is envisaged that development will continue in DTI (Denmark) and initial market traction may be garnered there based on pilot test results.

The optimum climate for the magneto caloric heat pump has not been established, meaning the effect and influence this concept will have in the market without making a number of assumptions with regard to the popularity of this product on the consumer market. It is noted warmer climates may be slightly more applicable with smaller temperature differences improving efficiency. Thermal envelope affects system performance so buildings with high insulation values are most suitable for this concept, and niche markets, where specialized requirements preventing conventional solutions may be applicable but will not be a large share of the market.

4.1.2 Multi-source heat pump

The multi-source heat pump is a smart and flexible multi-source heating system that uses renewable heat sources from the ground, water, air or another staged heat pump to create free energy. Multi source heat pumps are adaptable and come in a variety of sizes. The multi-source heat pump has a positive impact on the environment, due to decreasing CO_2 content in electricity networks making this one of the lowest (operational) carbon products on the market. Based on the system and market analysis, the multi-source heat pump would be most suitable in the Netherlands, Germany, Poland, Italy and Denmark.

System component	Ireland	Netherlands	Germany	Poland	Italy	Spain	Greece	Denmark
Multi source heat pump	-	+/-	+/-	+	+/-	-	-	+/-

While the multi-source heat pump would be suitable across all climates it is proposed to target to colder and extreme climates where optimal COP source can be selected as required to maximise efficiency.

The proposed target markets based on the analysis for the multi-source heat pump were selected as

- Larger building owners / facility managers in MFRB, Commercial & Public buildings

4.1.3 PV Thermal

Photovoltaic thermal collectors are power generated technologies that convert solar radiation into thermal and electrical energy. PV thermal collectors benefit the environment, while lowering the overall energy costs of a building.

PV thermal technology can produce renewable electrical energy and provide hot water from the one component increasing the renewable energy production density and reducing the space requirement.

Based on the system and market analysis, all countries were found to benefit from PV thermal. However, the countries least suitable for PVT were found to be Italy, Spain and Greece.

System component	Ireland	Netherlands	Germany	Poland	Italy	Spain	Greece	Denmark
PVT	+	+	+	+	+/-	-	-	+

In general, these 3 countries have warmer, sunnier climates which limits the requirements for space heating and high temperature domestic hot water, particularly in public and private ownership buildings with low hot water demand.

Additionally, those buildings with limited roof space available for solar systems such as MFRBs and SFHs would benefit from the greater renewable energy produced from limited space. Those with large roof space and limited thermal energy demand would benefit more from a more efficient dedicated solar PV system.

PVT technologies low TRL and cost is currently a barrier to market impact, but this is expected to be overcome with further industry development.

4.1.4 BTES & Controller

BTES is an improvement on conventional closed-loop ground source heat pump (GSHP) geothermal systems. The ground heat exchanger (GHX) array for a BTES system is designed and operated in a manner such that heat is stored or abstracted seasonally, whereas conventional GSHP systems are designed to simply dissipate heat or cold into the subsurface. BTES essentially uses the earth as a thermal battery, as opposed to a radiator.

BTES is most suitable in regions with extreme climates, with hot summers and cold winters. For countries that have a climate that remains stable and doesn’t have great temperature difference between Winter and Summer, air source heat pumps with water storage are typically more economical.

Based on the system and market analysis the following countries were selected as where BTES controller would be most compatible.

System component	Ireland	Netherlands	Germany	Poland	Italy	Spain	Greece	Denmark
BTES & Controller – GeoBooster	-	+	+/-	+/-	-	-	-	+

Geothermal energy and borehole thermal energy storage has vast potential in Denmark as although it has moderate temperature gradients, its widespread geothermal aquifers and district heating networks in most of the Danish towns provide a significant market for BTES type systems. Similarly, in recent years the Netherlands has seen an increase in operating geothermal projects. BTES requires developed geothermal market for applicability. This makes it easier for the adaptation of the BTES controller technology. The markets of Germany and Poland are growing with significant potential for energy storage solutions such as BTES.

For new build domestic developments, larger scale apartment blocks or estates in suitable geological areas would be the main market for BTES systems, likely as part of a hybrid heating and cooling solution with competing technologies.

The capital cost of a large BTES system can be significant, as a large number of geothermal boreholes will need to be drilled. However, the installation cost should be similar to conventional GSHP systems, and the higher COP values will result in a lower total life-cycle cost than a conventional GSHP system.

Furthermore, planning permission limitations and under, or over developed regulation of BTES need to be overcome.

4.1.5 IES Delivery Framework, System Simulation Platform & BEMS Optimisation software

IES co-design service allows for the involvement of one company/entity dealing with different technologies, engineering solutions, providing energy, design and financial consulting. The system simulation platform is a combination of system component simulation software and building models to identify the most suitable sizing of system components (e.g. heat pump capacity, tanks volume) to ensure that the estimated heating/cooling demand is covered. The Building Energy Management System (BEMS) and optimization solution will allow the user to operate their energy system as designed, enable accurate commissioning and on-going monitoring of performance which can be optimised based on collected data and developed optimisation algorithms.

IES design methodology, simulation platform and BEMS optimisation software are applicable to all energy system designs. The software is dependent on the input of different data. Both more useful in more complex designs commercial, MFRB & public building with larger systems and multiple stakeholders.

System component	Ireland	Netherlands	Germany	Poland	Italy	Spain	Greece	Denmark
Grey box models / Simulation Software	+	+	+	+	+	+	+	+
BEMS & BMS optimization	+	+	+	+	+	+	+	+
IES System Del.Framework	+	+	+	+	+	+	+	+

4.1.6 Overall Summary of Each Country

Summarizing the above and combining the most suitable technologies for each country (representing a target market climate/location) the proposed adapted RES4BUILD system applicable to each market as presented in the table below. From this it is clear to see the most versatile concepts which will work in each country compared with the concepts that are not as applicable across all EU regions. The results from this table will be used for the operational performance in the following section.

System component	Ireland	Netherlands	Germany	Poland	Italy	Spain	Greece	Denmark
Magneto caloric heat pump	-	-	-	-	-	-	-	+/-
Multi source heat pump	-	+/-	+/-	+	+/-	-	-	+/-
PVT	+	+	+	+	+/-	-	-	+
BTES & Controller – GeoBooster	-	+	+/-	+/-	-	-	-	+
System Simulation Platform	+	+	+	+	+	+	+	+
BEMS & BMS optimization	+	+	+	+	+	+	+	+
IES System Del.Framework	+	+	+	+	+	+	+	+

4.2 Operational Performance

The RES4BUILD system is developed in a flexible way to allow the use of single technologies and the integration of the selected system components such as the multi-source heat pump, BTES and the PVT collectors as required, as well as standard components, such as pure solar thermal collectors or PVs and air source heat pumps. This results in a variety of possible layouts that can be fine-tuned according to the market.

The most suitable RES4BUILD technology for each country taking into account the advantages and disadvantages of each technology and the countries market is summarized above. These countries and their associated RES4BUILD system design can be further grouped into target markets typifying their climates. These climates, as per D7.1 Project Impact report are Warm, Mixed-Moderate, Average, and Cold. Furthermore, the target markets can be divided into Residential (Res) including Single Family Homes (SFH) and Multi-Family Residential Buildings (MFRB), and Non-Residential (Non-Res) including Office and Public or School buildings.

For all of the target markets, the IES methodology, System Simulation Platform & BEMS Optimisation software are applicable to the design and operation of a bespoke RES4BUILD system. In contrast only certain system components were suitable to each target market as detailed above, with the bespoke system technology for each market, split between residential and non-residential, summarised below.

<table>
<tr><td rowspan="4">Warm Climate</td><td rowspan="4">Greece
Spain
Italy</td><td rowspan="2">Res : ASHP + PVT (no BTES)</td><td>SFH</td></tr>
<tr><td>MFRB</td></tr>
<tr><td rowspan="2">Non-Res: ASHP & PV</td><td>Office</td></tr>
<tr><td>School</td></tr>
<tr><td rowspan="4">Moderate Mixed</td><td rowspan="4">Ireland</td><td rowspan="2">Res : ASHP + PVT (no BTES)</td><td>SFH</td></tr>
<tr><td>MFRB</td></tr>
<tr><td rowspan="2">Non-Res: ASHP & PV</td><td>Office</td></tr>
<tr><td>School</td></tr>
<tr><td rowspan="4">Average</td><td rowspan="4">Netherlands
Germany</td><td rowspan="2">Res : MSHP + PVT + BTES</td><td>SFH</td></tr>
<tr><td>MFRB</td></tr>
<tr><td rowspan="2">Non-Res : MSHP + PVT + BTES</td><td>Office</td></tr>
<tr><td>School</td></tr>
<tr><td rowspan="4">Cold</td><td rowspan="4">Poland
Denmark</td><td rowspan="2">Res : MSHP + PVT + BTES</td><td>SFH</td></tr>
<tr><td>MFRB</td></tr>
<tr><td rowspan="2">Non-Res : MSHP + PVT + BTES</td><td>Office</td></tr>
<tr><td>School</td></tr>
</table>

It is noted that not all areas or regions of the countries researched will fit wholly into the climate applied (e.g. the northern mountainous regions Spain and Italy in the warm climate), and each target market would have a greater variance of building typologies and existing systems. However, for the purpose of this study it is assumed to be generally representative of the target markets.

The distinction of target markets in these groupings also enables a comparison of the operation and performance of the bespoke RES4BUILD integrated energy systems versus the original generic RES4BUILD system and a baseline gas boiler and air conditioning system in Europe from D7.1 Project Impact report.

Using the previously developed D7.1 Project Impact building demand models, and RES4BUILD System Simulation platform for the updated bespoke RES4BUILD system configurations for target market their performance and impact on the EU market is estimated.

EU Building Stock Thermal Energy & Emissions Impact Assessment			Baseline: gas boiler + AC Chiller		RES4BUILD Bespoke		R4B Baseline Impact	R4B Markets Bespoke
Location	Typology	Est. EU Rep. Building Floor Area	Gas use	Elec use	Gas use	Elec use	GWP Saving	GWP Saving
		million m2	GWh/yr	GWh/yr	GWh/yr	GWh/yr	% CO_2-e Saved p.a.	% CO_2-e Saved p.a.
Warm Climate Target Market	SFH	3,253	88,786	59,766	0	27,817	74%	79%
	MFRB	1,830	15,263	49,192	0	2,050	73%	97%
	Com. Office	521	2,528	16,706	0	1,162	53%	94%
	Public - School	295	4,082	3,078	0	-17,386	68%	367% *1
Moderate-mixed Climate Target Market	SFH	1,884	122,506	1,545	0	26,939	75%	74% *2
	MFRB	1,060	49,687	138	0	13,288	78%	68%
	Com. Office	324	7,778	1,227	0	521	48%	93%
	Public - School	183	7,459	143	0	-846	13%	113% *1
Average Climate Target Market	SFH	5,088	275,329	38,977	0	18,471	77%	93%
	MFRB	2,862	111,396	8,415	0	6,783	80%	93%
	Com. Office	858	20,950	11,603	0	-2,001	63%	107% *1
	Public - School	486	12,542	3,596	0	-12,889	36%	191% *1
Cold Climate Target Market	SFH	3,610	305,154	14,117	0	45,130	75%	83%
	MFRB	2,031	126,056	3,067	0	20,857	90%	81%
	Com. Office	590	18,620	7,749	0	12,511	55%	47%
	Public - School	334	11,605	2,361	0	8,344	23%	31%
Total building stock	EU28	25,211	1,179,741	221,677	**0**	**150,752**	**75%**	**88%**

As shown by the above operational impact model, the system and market analysis input to produce bespoke RES4BUILD energy systems optimally designed for target markets has increased the potential GWP reduction to 88%, compared to 75% for the original generic RES4BUILD system design with all components utilised.

These bespoke RES4BUILD energy system designs maximise cost and operational efficiencies associated with the target market climate, regulations, and socio-economic factors.

Observations / notes:

1. The Warm climate market a single source (likely air but water possible too) heat pump and combined PVT system is proposed for residential buildings with limited roof space and higher domestic hot water load. For non-residential spaces with typically low DHW demand a solar PV system is proposed to maximise the electrical energy production from the available roof space. As a result, the relatively low energy demand but large roof space (assumed 50% of 1750m2 area available for PV providing ~175 kWp system) of a public- school archetype building produces more electricity than it consumes providing extensive CO_2 savings greater than 100% in nearly all climates.
2. For the Mixed-Moderate climate market a similar single air source heat pump combined PVT system is proposed for residential buildings with limited roof space and higher domestic hot water load. However, even with the milder climate the removal of the availability of the BTES system compared to the generic RES4BUILD does reduce system efficiency for GWP reduction saving but greatly reduces expected system cost and regulatory issues. For non-residential spaces with typically low DHW demand a solar PV system is proposed to maximise the electrical energy production from the available roof space again provide net-positive CO_2 savings by producing excess electrical energy from the PV.
3. For the Average and Colder climate markets an optimised Res4BUILD system of multi-source heat pump, PVT and BTES system is proposed for both residential and non-residential projects. The MSHP can select the optimal source as required to maximise efficiency in cooler climates and still be low maintenance for residents and building owners. The power and solar thermal production in cooler climates also makes PVT suitable for both residential and non-residential markets, and the already well-developed geothermal markets in these regions promote BTES energy storage as a viable solution, albeit more likely on larger scale buildings.

The implementation of these bespoke RES4BUILD system designs into the target markets has the potential to reduce GWP CO_2e by an average of 88% across Europe.

As with the previous D7.1 Impact assessment model, these estimates assume that building fabric is updated independently and is also subject to social, economic and cultural variances across regions. However, the results indicate that implementation of the RES4BUILD solution, which is flexible to various markets, will reduce the GWP related to the heating and cooling of buildings in Europe.

It is clear that the upgraded Bespoke RES4BUILD system design further improves the GWP saving potential of the RES4BUILD components when tailored for the identified target markets. This highlights the importance of adopting an optimal approach for business models and IES Delivery Frameworks for the RES4BUILD system in the future.

5 Business Models

5.1 Introduction

The conclusion of sections 2, 3 and 4 which undertook a detailed regulatory and market analysis has resulted in development of business models for the optimal evolution of the system. This is split into the **market** and the **system** analysis, resulting in:

- EU-regions and property types to prioritize
- Definition of the minimum requirements for the business models
- Setup of integrated system options, applicable for specific climatic regions.

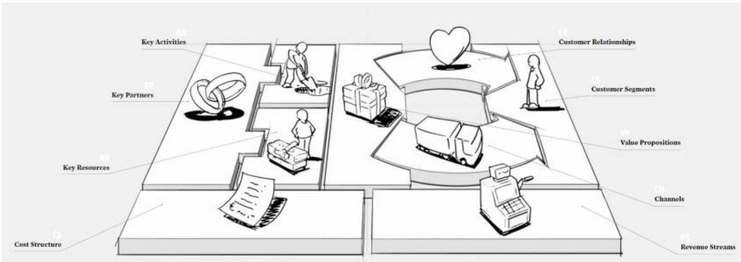


Figure 5-1: Business model canvas

Using the *Business Model Canvas* methodology as explained in the introduction and applied through these analyses, three examples are sketched which shall form the basis for the further roadmap of development.

In addition to this specific outcome, a methodology is shown which can be easily adopted by businesses starting the development of renewable energy system business models for existing property in the EU. This methodology, in combination with the presented data sources is useful to further detail the business model and/or replicate the analysis in the future.

5.2 Three examples

Following the conclusions in the Market Analysis, the prime direction for three prioritized business models is given in below. The conclusions from the system analysis are included.

These business models are a first direction. Following this setup, optimization & further detailing will be required similar as the system components need further development from the lower to higher TRL levels.

5.2.1 Poland, single family house, privately owned, rural

<table>
<tr><th>Key partners</th><th>Key activities</th><th>Value proposition</th><th>Customer relation</th><th>Customer segment</th></tr>
<tr>
<td rowspan="3">Municipalities / local bodies for setup of energy communities.

Subsidy providers to align compliance with geothermal and energy network requirements.

National bodies for alignment on continuity and clarity on electrical feed-in tariffs.

Assure continuity and clarity in funds for PV feed-in tariffs; push for increase in funding for thermal skin upgrade.</td>
<td>Providing IES as on Design, Build, Maintain and Operate (DBMO) basis.

Support initiation and managing of energy communities.</td>
<td rowspan="3">Thermal skin upgrade with minimum one EPC-level up. Including integral HVAC upgrade

Limited BEMS complexity; minimum smart metering.

IES based on multi-source VC heat pump. Based on LT heating / cooling assuming HVAC upgrades completed. Including BTES & Controller.

Solar energy through PV Thermal (high thermal demand and limited roof space). Combine with battery storage.</td>
<td>Involvement in system design and product selection based on existing house, using e.g. ‘building passports’.

Collaborating with energy community to select general approach and to stimulate collective sales.</td>
<td rowspan="3">Single family houses in rural areas (middle/low density); privately owned.

End customer is private, though preferable member of the energy community.</td>
</tr>
<tr><th>Key resources</th><th>Channels</th></tr>
<tr>
<td>Local suppliers for component production and installation.

(Intern)-national resources for (grey box) energy simulation and providing data management.</td>
<td>Energy communities (initiated by municipalities) providing links between the homeowners and local suppliers. Providing support in regulations.

Local suppliers connecting with energy communities; providing access to digital media for communication.</td>
</tr>
</table>

<table>
<tr><th>Cost structure</th><th>Revenue streams</th></tr>
<tr>
<td>Initial investment in passive and active components.
Operational costs for maintenance, data management, innovation, and replacements.
Operational costs for community engagement and policy translation into optimal control strategy.
End of life costs for demolishing and waste handling.</td>
<td>Non-financial support in replacement of inefficient system components throughout the lifetime (or initial renovation).
CAPEX support for renovation of residential buildings to higher EPC’s-level (passive and active measures).
CAPEX support for installation of PV or PVT & battery storage.
CAPEX support to attract from non-energy funds such as covid-recovery.
CO2 trading schemes during operation.
Monthly service fee paid by landlord.
Monthly (quite low) energy costs paid by the tenants.
End of life income for return of valuable materials.</td>
</tr>
<tr><th colspan="2">Foundation</th></tr>
<tr><td colspan="2">Follow regional targets for environmental performance as a minimum and add national, local or community targets to align with local practice. Adjust the targets over time, e.g. where now focused no ‘nearly energy neutral’ towards possible ‘completely emissions neutral’ in the future

Energy / service provider assures peak shaving in energy costs for vulnerable tenants, by providing long term continuity.</td></tr>
</table>

5.2.2 Greece, multi-family residential building, urban region, low income

<table>
<tr><th colspan="2">Key partners</th><th colspan="2">Key activities</th><th colspan="2">Value proposition</th><th colspan="2">Customer relation</th><th colspan="2">Customer segment</th></tr>
<tr><td colspan="2" rowspan="3">National bodies for alignment on continuity and clarity on electrical feed-in tariffs.

Surrounding buildings in energy cooperations: to collectively setup local heating/cooling networks using building exchange and geothermal sources.

Assure alignment with funds for PV systems if subsidies..</td><td colspan="2">Providing IES as on Design, Build, Maintain, Operate and Deconstruct (DBMOD) basis.</td><td colspan="2" rowspan="3">Improve thermal skin performance minimum one EPC-level up and include shading. Offer dry-built up systems for floor heating if required.

Integrate limited BEMS and smart metering.

System based on air source VC heat pump or chillers for cooling demand

Solar energy through PV Thermal (relatively high DHW demand and limited roof space per occupant). Combine with battery storage.

IES system on building level with individual connections to tenants.</td><td colspan="2">Through the current governmental alimony support bodies.</td><td colspan="2" rowspan="3">Multi-family residential buildings in lower density urban areas; having EPC-scores lower than C and high energy use per m2.

Ownership: owned by private landlord, serving (mainly low-income) tenants.

Contracts to sign with both the individual tenants and the landlord.</td></tr>
<tr><th colspan="2">Key resources</th><th colspan="2">Channels</th></tr>
<tr><td colspan="2">Local suppliers for system delivery/ installation.
Recruitment from current (closing) fossil energy plants.

(Intern)-national resources for (grey box) energy simulation and providing data management.</td><td colspan="2">Collaborate with financial support schemes to relate to tenants, supporting them to motivate the landlord to contribute.

Local fabrication of system components/ materials and short-distance distribution.

EU-wide data connections with aggregated data on energy use and system performance.</td></tr>
<tr><th colspan="5">Cost structure</th><th colspan="5">Revenue streams</th></tr>
<tr><td colspan="5">Initial investment in passive and active components.
Operational costs for maintenance, data management, innovation, and replacements.
Operational costs for community engagement and policy translation into optimal control strategy.
End of life costs for demolishing and waste handling.</td><td colspan="5">Non-financial support in replacement of inefficient system components throughout the lifetime (or initial renovation).
CAPEX support for renovation of residential buildings to higher EPC's-level (passive and active measures).
CAPEX support for installation of PV or PVT & battery storage.
CAPEX support to attract from non-energy funds such as covid-recovery.
CO2 trading schemes during operation.
Monthly service fee paid by landlord.
Monthly (quite low) energy costs paid by the tenants.
End of life income for return of valuable materials.</td></tr>
<tr><th colspan="10">Foundation</th></tr>
<tr><td colspan="10">Follow regional targets for environmental performance as a minimum and add national, local or community targets to align with local practice. Adjust the targets over time, e.g. where now focused no 'nearly energy neutral' towards possible 'completely emissions neutral' in the future

Energy / service provider assures peak shaving in energy costs for vulnerable tenants, by providing long term continuity.</td></tr>
</table>

5.2.3 Spain, public office building, owner/occupied

<table>
<tr><th>Key partners</th><th>Key activities</th><th>Value proposition</th><th>Customer relation</th><th>Customer segment</th></tr>
<tr><td rowspan="3">National bodies for alignment on continuity and clarity on electrical feed-in tariffs.

Surrounding buildings in the form of (Green) Business Clubs and/or energy cooperations: to collectively setup local heating/cooling networks using building exchange and geothermal sources.</td><td>Providing IES as on Design, Build, Finance, Maintain, Operate and Deconstruct DBFMOD basis.</td><td rowspan="3">Upgrade thermal skin with focus on solar protection.

Integrate full potential of BEMS in combination with smart systems and smart metering;

System based on air source VC heat pump or chillers for cooling demand.

Strong focus on PV (limited thermal on residential buildings for DHW) application in line with local policy, with limited battery storage due to feed in tariffs</td><td>Link the value proposition to behavioral improvements for energy reduction, through which users are linked with the building (manager).</td><td rowspan="3">Office buildings in the commercial and public sector, with owner and occupier in one organization with ‘shared incentive’.

In climatic zone which has some limited heating (Northern region) and significant cooling needs.

End customer shall be the public body, involved in CAPEX and OPEX.</td></tr>
<tr><th>Key resources</th><th>Channels</th></tr>
<tr><td>Local suppliers for system delivery/ installation.

(Inter)-national resources for energy simulation and providing data management.</td><td>Public tenders for project acquisition.

Local fabrication of system components/materials and short-distance distribution.

EU-wide data connections with aggregated data on energy use and system performance.</td></tr>
</table>

Cost structure	Revenue streams
Initial investment in passive and active components. Operational costs for maintenance, data management, innovation, and replacements. Operational costs for community engagement and policy translation into optimal control strategy. End of life costs for demolishing and waste handling.	CAPEX support for renovation of public buildings. CAPEX Subsidies for introduction of new business models. CAPEX support for installation of PV & battery storage. CO2 trading schemes during operation. Monthly service fee paid by public body End of life income for return of valuable materials.

Foundation
Follow regional targets for environmental performance as a minimum and add national, local or community targets to align with local practice. Adjust the targets over time, e.g. where now focused no ‘nearly energy neutral’ towards possible ‘completely emissions neutral’ in the future

5.3 Optimization of Routes to Market

Following on from the previous sections review of the business model approach to market readiness, there is a need to develop a roadmap to detail country specific targets and optimization. This will be part of the upcoming roadmap task and deliverable D7.3

The method for optimization could be based on the 'Blue Ocean Strategy' which helps to simultaneously increase (environmental/customer) value while reducing costs (or negative impact). This is achieved by identifying which elements of the Value Proposition can be **eliminated, reduced, raised,** or newly **created.** There are two goals:

1. To lower costs/negative impact by reducing or eliminating less valuable features or services.
2. To enhance or create high-value features or services that do not significantly increase the cost base or generate additional income.

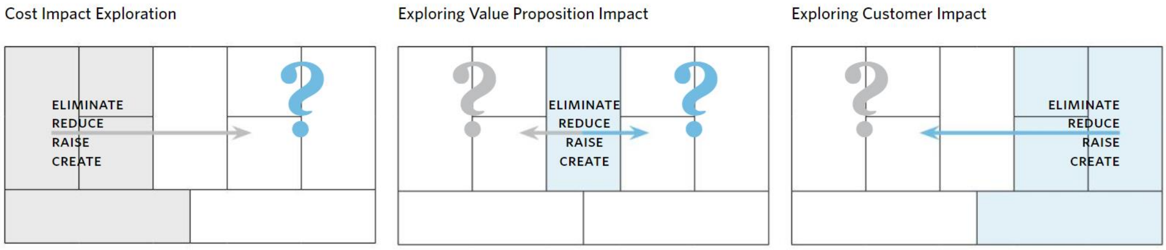


Figure 5-2: Optimization routes

It can be concluded from the example-business models that significant cost can go into communication and organization of energy communities, cooperations and/or business clubs. The investment is intended to pay back from either improved system performance (based on exchange or upscaling) and targeting a larger customer group. For some regions, this approach is stimulated and will be more viable than others. The value is understood, but cost reduction should be achieved through voluntary collaboration of the community itself.

Operational costs will form the majority of the total life cycle, as this includes periodic upgrades to keep up with legislation, service and maintenance, data handling and administration over a long period of time. Energy costs/income are excluded as most regulation restricts feed-in tariffs to the individual user. If alternatives could be found where the energy cost reduction could fall in benefit of the IES-supplier, this would improve the business model in operational phase.

The value proposition is primarily based on the IES components, while battery storage is proposed. Based on upcoming regulation, it is expected that integration of this element will benefit the pay/cost ratio for individual PV. Though, the investment on building level in batteries will mostly benefit the grid supplier, as grid connection tariffs at this moment do not take into account available storage capacity.

D7.2 Market Analysis and Business Models

Appendices

Public

Deliverable 7.2

December 2022

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1 Appendix I: EU Policy Context

RES4BUILD's aim of mitigating the Global Warming Potential (GWP) in the built environment by leveraging renewable energy systems aligns with the goals of many EU Policy initiatives. It is set in the context of the Paris Agreement which in 2015, set a global agenda to ensure policy compatibility with a 'well below 2 degrees Celsius' world. The European climate policy frameworks are aligned to ensure consistency with the goals of the Paris Agreement, which are primarily focused on improved energy efficiency, renewable energy generation and shifting to low or zero carbon fuels.

Most of the EU's current and future legislation is directed towards climate action and net-zero goals. There are many policy actions aimed at improving the fabric and energy efficiency of new and existing buildings, including net zero- carbon heating solutions**,** planning for the full phase out of fossil fuels in buildings by 2050, progressive strengthening of building standards for all types of buildings, promoting the use of lower carbon alternatives in construction and promoting behavioural change in how households use energy. Therefore, the focus of RES4BUILD is entirely aligned with the climate agenda as set out across the EU policy landscape and enables progress towards targets in the relevant sectors such as the energy markets and building infrastructure.

EU Policies which drive the climate agenda across the region, and which are relevant to RES4Build project are listed below:

1.1 European Green Deal

The European Green Deal is an integral part of the European Commission's strategy to implement the United Nation's 2030 Agenda and the sustainable development goals. As part of the European Green Deal, with the European Climate Law, the EU has set itself a binding target of achieving climate neutrality by 2050. The Green Deal strives for a socially just transition and is centered around the following action themes:

The implementation of the European Green Deal will drive action across the region, setting the precedent for policy and legislative reform, which will underpin the technological, infrastructural, and financial pathways to achieve climate neutrality by 2050. All sectors will be required to decarbonise their operations and supply chains by implementing the necessary energy and carbon saving measures, opting for green procurement options, and availing of services that have met decarbonisation requirements.

The Green Deal is contributing to the societal shift in attitudes, helping to bring the climate agenda to the forefront of government, business, and organisational priorities. The effects of which cascade to users and consumers, many of whom have new expectations around sustainability and decarbonisation, which may impact their decisions around availing of certain products and services. There can be issues with regards to planning and development consents for new developments if it cannot be shown how the development will contribute to European and Member State carbon reduction targets. The European Green Deal provides for new and/or increased requirements to reduce energy demands and source clean energy. There is a requirement for cutting-edge technological innovation across the energy sector to provide clean energy sources. Moreover, it provides for a renewed focus on the property and asset management sector, aiming to significantly increase the rates of building renovation to ensure energy efficient buildings, with reduced emissions. The implications of not abiding by these binding goals or failing to achieve the charted-out targets will leave businesses open to physical, transition, liability, and reputational risks.

The impact is defined as the result of certain pressures (e.g., GHG emissions, water abstraction, etc.) that the activity exerts on the state of the environment (e.g., local water availability of the activity area, atmospheric GHG concentration, etc.). Hence, the impact will depend on the environmental performance of the activity (i.e., the pressures it exerts) but also on the context in which the activity takes place. Activities qualify if they operate above or below a given threshold.

The European Green Deal Investment Plan (EGDIP), also referred to as Sustainable Europe Investment Plan (SEIP), is the investment pillar of the Green Deal. The EGDIP has three main objectives:

- Mobilize at least €1 trillion to support sustainable investments over the next decade through the EU budget and associated instruments, in particular InvestEU
- To create an enabling framework for private investors and the public sector to facilitate sustainable investments
- Providing support to public administrations and project promoters in identifying, structuring, and executing sustainable projects.

This plan will redirect funding flows towards sustainable project development, both small (e.g. household energy renovation) and large (e.g. installation of a network of electric vehicle charging stations). Part of the plan includes the Just Transition Mechanism, which focuses on supporting citizens most impacted by the transition.

1.2 European Climate Law

The European Climate Law is the first law of its kind. It enshrines into European law two main goals. The first is the main goal of the ultimate European Green Deal, which is to be net climate neutral by 2050. The second goal is the reduction of net greenhouse gas emissions by 55% relative to 1990 levels by 2030. The law sets the direction of the EU's climate agenda, as all sectors of society must now align and so most EU plans and policies are linked to this. The law came into force in July 2021. The law aims to ensure a socially just and cost-effective transition. Progress will be reviewed every 5 years, in line with the global stock take exercise under the Paris Agreement

This will enshrine in law the EU's framework to achieve its 2050 climate neutrality. The details of implementation remain to be defined but this will have implications for both climate mitigation and adaptation. There is pressure on public administrations to provide policies in compliance with climate neutrality goals. Having carbon neutrality written into climate law in each Member State means that action for fast decarbonization will cascade down to all sectors, with increasingly stringent carbon reduction requirements in all fields of the economy. A major review of the reductions achieved in 2030 will lead to further effort. Failure to stay abreast of the requirements of the European Climate Law will leave businesses open to physical, transition, liability, and reputational risks.

1.3 EU Fit for 55 Package

Fit for 55 is a package of policy proposals drafted by the European Commission. Collectively, the package aims to reduce the EU's greenhouse gas emissions by 55% by 2030, relative to 1990 levels, responding specifically to the second objective of the European Climate Law (55% greenhouse gas emission reduction by 2030). It comprises a mix of existing and new policies, using the following instruments: carbon pricing, regulation, changes to standards and creation of funds. As of early 2022, negotiations surrounding the adoption of policy proposals put forward by the fit for 55 package are still ongoing. Should the package be adopted, there will be significant changes to the buildings sectors as the scope of existing (and new) policies is expanded to include these sectors.

1.4 2030 EU Climate Target Plan

The EU Climate Target Plan outlines the pathway for the EU to achieve its legally binding 2030 climate target (55% net reduction in greenhouse gas emissions). The plan increases targets outlined in the existing 2030 Climate and Energy Framework, including targets for renewable energy and energy efficiency in addition to greenhouse gas emission reductions. The plan also aligns with the key objectives of the Paris Agreement. Overall, the plan delivers on the EU's commitment to put forward a comprehensive plan to give certainty to investors, policymakers and decisionmakers and comprises many aspects that form part of the European Green Deal and the proposed Fit for 55 Policy package.

This plan sets out measures required across all sectors, including targets for increased energy efficiency and renewable energy. This plan sets a framework for other policies and legislation which will drive action and enable the EU to move towards a climate-neutral economy.

1.5 Emissions Trading Systems (ETS)

This is a European system for trading greenhouse gas emission allowances with the aim of gradually reduce greenhouse gas emissions in a cost-effective manner. It works by putting a limit ("cap"), which is lowered over time (annually), on the total greenhouse gases that can be emitted by energy intensive activities. Under the system, the installations receive or buy emission allowances. They can "trade" these with other installations as needed. Each emissions allowance is for one ton of CO2 equivalent. Each year, an installation must have enough allowances to cover all its emissions, or otherwise it is fined. The ETS was launched in 2005 with the adoption of the ETS Directive which sets out the ETS legislative framework. The ETS Directive is updated through various trading phases. It is currently into its fourth trading phase (2021-2030) – however further updates to the ETS have been proposed under the Fit for 55 package to reflect the new EU 2030 targets

The ETS comprises a variety of heavy polluting sectors, primarily heavy energy-using installations consisting of power stations and combustion plants. The carbon price corridor in the EU ETS has increased at an accelerated rate from 2020, skyrocketing in 2021 (much faster than expected from the predicted modelling scenarios), showing a strong demand in the carbon market. The ETS introduces further requirements for innovative renewable energy sources and energy storage technologies.

Under the Fit for 55 Package, the Commission is proposing that emissions from the current EU ETS sectors be reduced by 61% by 2030, compared to 2005 levels, which would require annual emissions reductions of 4.2% per annum (instead of 2.2% per year under the current system). The cost associated with emissions permits is set to continue increasing, exposing sectors to extreme price volatility and transitional risk, as has already been seen under the current ETS.

It is also proposed that emissions from fuels used in road transport and buildings will be covered by a new, separate ETS, which will become operational as of 2025, with a cap on emissions set from 2026. Member States will be required to spend their auction revenues from emissions trading on climate, and energy-related projects, including decarbonization in the road transport and buildings sectors. It will be paramount that all sectors understand the requirements of the scheme depending on the geography, level of development and commitment, and the consequences of not meeting targets must be realized.

1.6 Effort Sharing Regulation

This is an EU law that sets binding yearly emission reductions for the Member States. It is part of the EU's implementation of the Paris Agreement and is a progression of the Effort Sharing Decision (2013-

2020). The Effort Sharing legislation establishes binding annual greenhouse gas emission targets for Member States from Non-ETS Sectors, most sectors not included in the Emissions Trading System (ETS). These sectors, including transport, buildings, agriculture, non-ETS industry and waste, which accounts for almost 60% of total domestic EU emissions. It sets national emission reduction targets for 2030 for all Member States. The Regulation continues to recognize the different capacities of Member States to take action by differentiating targets according to gross domestic product (GDP) per capita across Member States.

The Effort Sharing Regulation requires broad range of sectors take action to decarbonise, including analyzing the potential impacts and future investment needs. The Effort Sharing Regulation is implemented by the individual Member States, thus the requirements and local emission targets are nationally dependent. There will be significant infrastructure changes required across multiple sectors to ensure targets can be met. Specifically for RES4BUILD, the market context is very relevant as the Effort Sharing Regulation requires that buildings undergo energy efficient renovations to incorporate energy saving measures. There are fiscal and financial instruments defined for building systems to implement such measures.

To meet the EU's overall emission reductions target by 2030, the Commission proposed to reduce emissions under the Effort Sharing Regulation (ESR) by at least 40% from 2005 levels compared to the existing target of 29%. The new Member State targets will span from 10% to 50% reductions compared to 2005 emissions (previous targets ranged from 0% to -40%).

The proposed changes to the Effort Sharing Regulation requires increased commitments across sectors to accelerate decarbonisation. It is key that businesses understand the requirements of the regulation and realize localized targets. It may be essential to consider co-financing schemes to meet requirements, and to implement targeted investment. There are risks associated with market readiness and the availability of services. The buildings sector will be regulated by the new Emissions Trading System and the Effort Sharing Regulation (ESR). In recent times the buildings sector has not achieved adequate emissions reductions and thus implementing both regulatory systems (ETS and ESR) will ensure the required decarbonisation targets are met for the sector. The public sector will be required to renovate 3% of its buildings going forward.

1.7 Renewable Energy Directive

The Renewable Energy Directive set the legal framework for the development of renewable energy across all sectors of the EU economy. The objectives of the directive are to set obligatory EU Member State targets on renewable energy. To do this, the RED outlines a set of common principles, rules and standards to drive renewable energy technologies. The implementation of the Renewable Energy Directive removed barriers, stimulated investments, and drove cost reductions in renewable energy technologies. The Directive aimed to empower citizens, consumers, and businesses to participate in the clean energy transformation.

RED II is the revised and current version of the Renewable Energy Directive. The overall EU target for Renewable Energy Sources consumption by 2030 has been raised to 32%, with a clause for a possible upwards revision by 2023 and comprises measures for the different sectors to make it happen. This revision was enforced in December 2018, as part of the as part of the Clean Energy for All Europeans Package, helping the EU to meet its emissions reduction commitments under the Paris Agreement.

The revised Directive strengthens the role of guarantees of origin in tracking renewable energy supporting renewable Power Purchase Agreements (PPAs) by providing traceability. Renewable PPAs can support the route to market and business case for renewable energy clients and can help to stabilize the electricity market, protecting against future price volatility. The revision includes increased targets and strengthens criteria for ensuring bioenergy sustainability including accountability for processing and supply chains which must be considered at development stage.

RED III is a proposed update to the existing Renewable Energy Directive II. The purpose of the update is to better align the directive to the European Green Deal specifically the 55% greenhouse gas emission reduction by 2030 target and was put forward under the Fit for 55 package. The RED III proposal proposes to increase the Renewable Energy Sources consumption to 38-40% by 2030. As of early 2022, negotiations are ongoing between the European Parliament and the European Council. The directive was made operational in July 2022.

The RED III will set an increased target to produce 40% of EU energy from renewable sources by 2030. The proposed revision would enable EU energy systems to become more flexible, making it easier to integrate renewables into the grid as efficiently as possible and supports the uptake of renewable hydrogen where electrification is more difficult. The RED III will make additional provisions to support renewable Power Purchase Agreements (PPAs) which should drive further growth in the accelerating market for renewable PPAs which can support the route to market and business case for renewable energy clients. One of RED III's requirements that RES4BUILD directly addresses is that the new RED will require more energy efficient buildings and increased requirement for the use of renewable energy in buildings.

1.8 Energy Performance Buildings Directive (recast)

The Commission presented its 'Renovation Wave' strategy to boost energy renovation of buildings in the EU in 2020. The strategy contains an action plan with the goal of doubling the annual energy renovation rate of buildings by 2030. This goal requires a revision of the Energy Performance of Buildings Directive (EPBD) which was first published in 2002 with subsequent revisions in 2010 and 2018. Since the 2010 revision, the EPBD requires that energy performance requirements should consider the life cycle cost of buildings. This means also taking into account of the operational, maintenance, disposal and energy costs of buildings and building elements.

The EPBD 2018 revision includes the five 'overarching' EPB standards (ISO) for the energy performance of buildings. The next revision of the EPBD is an essential part of the Renovation Wave strategy and will focus on provisions that will accelerate the rate of building renovation. The proposal introduces a definition of zero-emission buildings, deep renovations, portfolios, 'Renovation passports' and new preformation metrics (such as energy consumption and lifecycle carbon). The proposal is designed to work together with the new emissions trading system for buildings proposed under the Fit for 55 Package. The proposed revision to the EPBD is set to be adopted in 2022.

The proposed measures will increase the rate of renovation, particularly for the worst-performing buildings in each Member State. The revision will introduce an increased requirement for property owners to implement targeted investment in the appropriate refurbishments, renovations, technologies and energy efficiency improvements across their building stock to meet minimum standards. The proposed revision supports the digitalisation of energy systems for buildings and provides flexibility in taking account the differences in building stocks across the EU.

Summary of requirements & incentives:

- All new buildings to be **NZEB** as of 2020

- Member States are obligated to define **major renovations** as either: the total cost of renovation of the building envelope or the technical building systems is higher than 25% of the building value (excluding land), or more than 25 % of the surface of the building envelope undergoes renovation, and should then encourage highly efficient alternative systems (such as RES4Build) for buildings undergoing major renovations.
- Wider benefits which relate to the encouragement for **material recycling**.
- **Trigger points** provide guidance on the undertaking of energy efficient renovations at building trigger points, which are “an opportune moment in the life-cycle of a building, for example from a cost-effectiveness or disruption perspective, for carrying out energy efficiency renovations”.
- **Building renovation passports** are a new addition to the 2018 recast of the directive and is an optional document complementary to the EPC which provides a long-term, step-by-step renovation roadmap for a specific building based on quality criteria, following an energy audit, outlining measures and renovations to improve energy performance. These passports will aid in measuring the compatibility of a building with the RES4Build system. The European Commission is establishing policy options for the possible introduction of additional (non-legislative and legislative) measures at EU level to support building renovation passports, including an optional building renovation passport scheme under the EPBD.
- The concept of a **Smart Readiness Indicator** was introduced in the 2018 EPBD recast. The Commission was required to develop an optional common EU scheme for rating the smart readiness of a building, which will be based on “an assessment of the capabilities of a building or building unit to adapt its operation to the needs of the occupant and the grid and to improve its energy efficiency and overall performance.”
- The smart readiness indicator will raise awareness amongst building owners and occupants of the value behind building automation and electronic monitoring of technical building systems and should give confidence to occupants about the actual savings of those new enhanced functionalities. This will allow for confidence in the RES4BUILD system, which will utilise a BEMS system that is capable of controlling building thermal demand and ensuring comfort without wasting energy.
- A technical building system is defined as technical equipment for space heating, space cooling, ventilation, domestic hot water, built-in lighting, building automation and control, on-site electricity generation or a combination thereof, including those systems using energy from renewable sources, of a building or building unit. Under the EPBD, Member States are required to set system requirements for the overall energy performance, proper installation and appropriate dimensioning of these systems. The RES4Build system would also be subject to these requirements, as it is a technical building system. As RES4Build uses BEMS, buildings equipped with the system would be exempt from mandatory regular inspections of the accessible parts of heating systems and combined heating and ventilation systems.

1.9 Energy Efficiency Directive

The proposal for a new Energy Efficiency Directive would raise the level of ambition of the EU energy efficiency target and make it binding. The new directive would recast the 2012 Energy Efficiency Directive which was amended in 2018. It would require EU Member States to collectively ensure an additional reduction of energy consumption of 9% by 2030 compared to 2020. This proposal responds to the European Climate Law (specifically the 2030 objective that mandates a 55% net greenhouse gas emission reduction) and will be introduced under the Fit for 55 Package. This proposal is interlinked with many of the other policies proposed under the Fit for 55 Package. It has been put forward by the European Commission but has not yet been adopted.

The proposal focuses on sectors with high-energy savings potential, notably heating and cooling, industry, and energy services, and puts additional emphasis on the public sector for the example that it can serve in leading the transition. The proposal includes measures to boost renovation in a way that benefits society in terms of addressing energy poverty and strengthening consumer empowerment. For the public sector, the Council agreed that member states would be required each year to renovate at least 3% of the total floor area of buildings owned by public bodies.

1.10 Clean Energy for all Europeans Package

The Clean Energy for all Europeans Package is a package of 8 laws that provide an EU-wide framework to help the EU move away from fossil fuels, to deliver on the EU's energy targets under the Paris Agreement, and to take steps towards implementing the Energy Union Strategy. The package aims to bring benefits to consumers, the environment, and the economy. The package was finalized in 2019 and EU countries had 1-2 years to transpose the new directives into national law. The legislation put forward in the Clean Energy for all Europeans Package will be further updated to align with new EU targets under the Fit for 55 Package.

The package consists of eight legislative acts on the energy performance of buildings, renewable energy, energy efficiency, governance, and electricity market design. Unlike previous energy packages, it does not include specific legislation for the gas sector. This package paved the way for a gradual transition away from fossil fuels and towards a carbon-neutral economy, driving action in relation to GHG emissions, renewable energy systems and energy efficiency.

1.11 EU Adaptation Strategy

The EU Adaptation Strategy sets out how the European Union can adapt to the unavoidable impacts of climate change and become climate resilient by 2050. The strategy focuses on developing and rolling out adaptation solutions to help reduce climate-related risk, increase climate protection, and safeguard the availability of fresh water. The strategy also proposes actions to gather more and better data on climate-related risks and losses and enhance Climate-ADAPT as the European platform for adaptation knowledge. This strategy resulted from the European Green Deal and was adopted on February 20.

There will be requirements for all sectors to become resilient to the effects of climate change, to reduce the risk of significant loss and damages in the long-term. This will require strategic planning, investments, and development to ensure the appropriate infrastructural and technological changes are implemented to reduce risk and safeguard assets from climate related risks. The strategy includes measures to improve data gathering which will minimize uncertainties around planning and investment and improve targeted risk reduction.

1.12 EU Circular Economy Action Plan (New)

In 2020, the European Commission adopted a new Circular Economy Action Plan for 2020, one of the main blocks of the European Green Deal. The new action plan supersedes the previous Circular Economy Action Plan (2015-2019) which completed its 54 actions by 2019 and was the first circular economy plan to be adopted by the European Commission. The new Circular Economy Action Plan (2020) identifies construction as a key area where there are opportunities for resource efficiency and circularity. The EU’s transition to a circular economy will reduce pressure on natural resources and will play an important role in decarbonization. The new action plan identifies legislative and non-legislative measures along the entire life cycle of products, considering design and ensuring waste is prevented, keeping resources in the EU economy for as long as possible. The plan focuses on the sectors that use most resources and where the potential for circularity is high such as: electronics and ICT, batteries and vehicles, packaging, plastics, textiles, construction and buildings, food, water, and nutrients.

The overarching objective of this action plan is to shift the focus away from waste disposal and treatment to ensure that materials and products remain in productive use for longer thereby preventing waste and supporting reuse through a policy framework that discourages the wasting of resources and rewards circularity. This is a broad policy that develops on the previous plan and will contribute to keeping sustainable development high on the agenda, continuing to unlock opportunities for clients in this sector, particular around incorporating circular economy principles into construction and ICT. The plan intends to revise EU waste legislation focusing on material recovery targets for construction and demolition waste, and its material-specific fractions.

The plan includes the intention to increase material efficiency and reduce climate impacts through a new comprehensive Strategy for a Sustainable Built Environment. This strategy will promote circularity principles throughout the lifecycle of buildings by integrate life cycle assessment in public procurement and the EU sustainable finance framework.

1.13 Social Climate Fund

The Social Climate Fund is a proposed EU mechanism to finance temporary direct income support for vulnerable households that results from increased energy costs arising from EU energy transition policies. Specifically, it is part of the key 'social fund' pillar of the proposed Fit for 55 package of proposals that collectively aim to reduce EU greenhouse gas emissions by 55% by 2030 in a just and economically viable manner. This pillar recognizes that the poorest in society will be the hardest hit as energy prices inevitably rise as a consequence of the proposed package, especially considering the inclusion of the roads and buildings sectors in the EU Emissions Trading Scheme. Therefore, the fund aims to alleviate this financial burden through redistribution. It will be partly financed by revenues generated as part of the EU Emissions Trading Scheme. As of early 2022, the Social Climate Fund had not yet been agreed or implemented.

This fund will create opportunities for clients to reinvest in sustainable development projects and thus further reduce emissions which can increase potential profit from emissions trading and support the business. There is risk of challenges associated with understanding the framework and developing internal procedures. For housing associations, the new Social Climate Fund will provide financial support to citizens, in particular the vulnerable households, to invest in renovation or heating systems and ensure a fair transition.

1.14 Renovation Wave

Renovating both public and private buildings is an essential action and has been singled out in the European Green Deal as a key initiative to drive energy efficiency in the sector and deliver on objectives. It aims to double annual energy renovation rates in the next 10 years. As well as reducing emissions, these renovations will enhance quality of life for people living in and using the buildings and should create many additional green jobs in the construction sector.

The Renovation Wave identifies three focus areas as follows:

- Tackling energy poverty and worst-performing buildings
- Public buildings and social infrastructure
- Decarbonising heating and cooling

With nearly 34 million Europeans unable to afford to heat their homes properly, renovation also tackles energy poverty. It can address the health and well-being of vulnerable people while reducing their energy bills – as outlined in the Commission recommendation on energy poverty, also part of the renovation wave strategy.

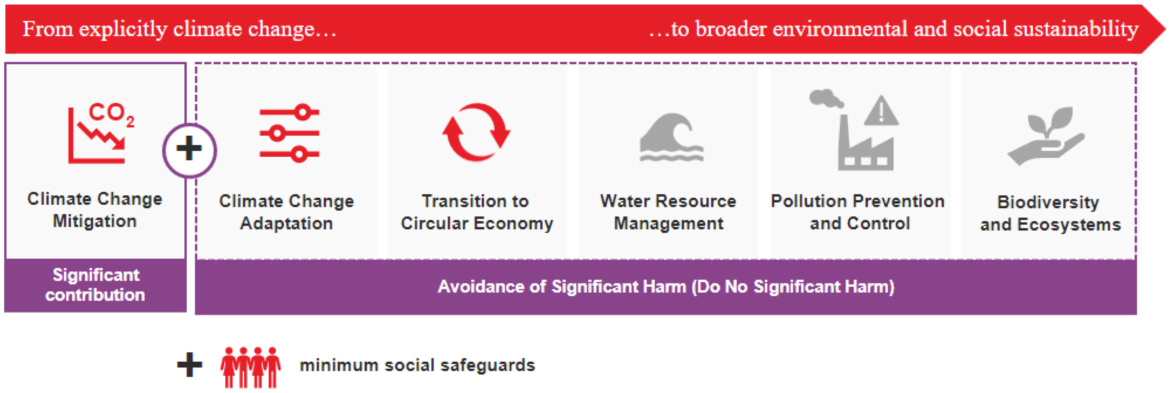
1.15 EU Taxonomy

The EU Taxonomy is a framework and classification system that aims to systematically define sustainable economic activities (EAs) across all industries in the EU, therefore reducing the potential for greenwashing. EAs currently in scope include activities in the following sectors: energy, transport, agriculture, manufacturing, ICT, and real-estate. Mandatory reporting is required for financial market participants offering financial products within the EU, and companies that fall under the Non-Financial Reporting Directive (and soon the Corporate Sustainability Reporting Directive). Companies are required to disclose the sum of their taxonomy-aligned capex/opex and what proportion this is of the total. In addition, the EU and member states are required to use the Taxonomy as a benchmark when establishing public measures, standards, or labels for green financial products or green (corporate) bonds.

The EU Taxonomy Regulation was officially published on 12 June 2020, establishing the framework for a common sustainable investment classification system. While it is not mandatory for companies to ensure their economic activities meet the criteria of the Taxonomy, it provides a motivation for companies to strive to reach a level of environmental performance that financial markets recognise as green. Taxonomy covers all sectors that are responsible for at least 80% of the direct GHG emissions in Europe. The Taxonomy Regulation defines 6 environmental objectives. In order to be 'taxonomy-aligned', gain “green label”, and attract taxonomy-aligned finance, economic activities must make a substantial contribution to at least one objective and do no significant harm to the other 5, while also meeting additional safeguard standards. The 6 objectives are:

- climate change mitigation
- climate change adaptation
- sustainable use and protection of water and marine resources
- the transition to a circular economy
- pollution prevention and control
- the protection and restoration of biodiversity and ecosystems.

These environmental objectives are relevant to the following sectors: urban-scale activities, buildings, materials/products, and infrastructure.



As explained in the EU Taxonomy overview, an economic activity must make a substantial contribution to at least one objective, in addition to other requirements, to be considered taxonomy-aligned. To define the substantial contribution, first it is essential to understand what the objectives are in terms of their end-state targets, how they interact and what sort of contribution should be expected through an implementing activity. The draft JRC report "Development of the EU Sustainable Finance Taxonomy - A framework for defining substantial contribution for environmental objectives 3-6" focuses on how to describe the substantial contribution (SC), as well as specifying seven possible approaches that can be used to assess the contribution of an economic activity. In this context, the environmental objectives are defined in relation to the DPSIR Framework (Driver, Pressure, State, Impact, Response) to establish the development of environmental indicators in the context of policy monitoring and development.

1.15.1 Substantial contribution types

According to the JRC report, there are three main ways in which an activity can make a substantial contribution (SC) to an environmental objective. The first two main types of substantial contribution are related to the own performance of the economic activity, while the third type is about enabling the own performance activities. It is worth noting that these types of substantial contribution vary in their applicability to the different environmental objectives.

1. Reducing pressure on the environment

Three different types of activities that substantially contribute to reducing the pressure on the environment are considered as following:

- Economic activities that generally are responsible for a significant pressure on the environment in relation to the relevant environmental objective, but with high improvement potential. They make a substantial contribution if performed in a way that reduces the pressure on the environment compared to the baseline (i.e., the likely alternative scenario). Undertaking of the activity compared to a no activity taking place scenario would be a negative impact on the environment. However, the impact will be significantly lower compared to the activity that would likely be carried out instead. As a result, by substituting activities exerting higher environmental pressures there is a substantial reduction of the environmental pressure. This must be considered in the context of each environmental objective, and applicability may vary as detailed in section 6.
- Activities that have a low environmental impact:
    - And have the potential to substitute high-impact activities, therefore, significantly reducing the overall pressure that is exerted on the environment. This needs to be justified based on the life cycle consideration. A contribution in this context cannot

be considered substantial if it shifts the environmental burden to another life cycle stage. While many activities across the economy have a low environmental impact (education for example), not all of them replace high impact activities. An example is electric vehicles that can make a substantial contribution by replacing more polluting vehicles internal combustion engines vehicles.

- And are helping to substantially reduce the pressure that other activities are exerting on the environment. The environmental benefits achieved from reducing the environmental impact of other activities must substantially outweigh the impact the activities themselves exert on the environment. Urban wastewater treatment is an example of such activities as this is an activity that substantially reduces the impact of activities discharging wastewater by removing pollutants from the wastewater effluent before it is further discharged back into the environment.

2. Directly improving the state of the environment (activities 'healing the environment')

The aim of this type of activities is to enhance the environment and contribute to achieving a good environmental status. These economic activities make a net positive contribution to the environment, therefore leading to a positive environmental impact.

3. Enabling activities

These are economic activities that directly enable other activities to make a substantial contribution. In line with Article 16 of the Taxonomy Regulation, these activities must not lead to lock in assets that undermine long-term environmental goals, and their environmental impact must be positive over the life cycle (i.e., the benefit that is enabled must be larger than the impact of the enabling activity).

1.15.2 Possible approaches in assessing the contribution of an economic activity

The term approach in this context refers to one of the ways to set criteria. The approach covers the way in which (1) the environmental performance of an activity is measured or assessed (e.g., quantitative vs. qualitative, units used) and (2) how the required level of environmental performance can be defined (e.g., implementation of certain practices, baseline, or comparison group). The seven approaches defined in the JRC methodology are:

1. Impact-based approach: Criteria set using this approach require an activity to demonstrate a certain level of impact regarding the environmental objective considered. This impact depends on the environmental performance of the activity and on the context in which the activity takes place.

2. Performance in relation to the environmental target: criteria set using this approach require an activity to demonstrate a certain level of performance. In contrast to the first approach, this performance-based approach is independent of the context in which the activity takes place and only relies on the intrinsic performance of the activity.

3. Best-in-class performance: Like for the previous approach, criteria set using this approach require an activity to demonstrate a certain level of environmental performance of the activity. Activities qualify if they operate above a threshold that is based on the performance currently achieved by the best performers (e.g., the level of performance achieved by the top 10% best activity operators in the EU).

4. Relative improvement: In this approach, the criteria require a minimum evolution of a given metric over time. This can be the performance improvement of an underlying activity or asset (e.g., improving the energy performance of a building for a renovation activity), the improvement in the state of the environment (e.g., reducing the amount of water pollutants by X% for a cleaning activity), etc.

Activities qualify if they can demonstrate an improvement by at least a defined relative threshold (e.g., an energy efficiency improvement of at least 20% compared to a previous point in time).

5. Practice-based: Criteria set using this approach require an activity to demonstrate implementation of or compliance with a set of defined practices or a list of qualitative requirements that are likely to substantially reduce the pressure on the environment or to substantially improve the state of the environment. These criteria describe how the activity must be performed. Activities qualify if they follow those practices.

6. Process-based: Criteria set according to this approach define a number of qualitative process-based steps to determine how to reduce the pressure or enhance the state of the environment in the case of the specific activity. Activities qualify if they follow the process steps detailed in the criteria and implement or achieve the requirements stemming for them.

7. Nature of the activity: Criteria set using this approach define the exact scope and description of the activity. Activities qualify if they fall within such scope/description. The activities are then taxonomy-aligned without being subject to quantitative or qualitative requirements.

To ensure that the approach used for defining the technical screening criteria is suitable, it must meet the following four conditions:

policy coherence: where appropriate, the approach makes it possible to build on EU legislation, approaches, and policy goals.

environmental ambition and integrity: the approach makes it possible to follow scientific evidence and take into account life cycle considerations.

level playing field: the approach allows fair treatment of activities within the same sector.

usability of the criteria: the approach makes it possible to develop criteria that are of easy and unambiguous to implement and verify.

However, the degree of compliance of each approach with each requirement depends on the environmental objective, on the type of substantial contribution and on the sector and activity considered.

In this context, activities that are relevant to RES4Build are:

- Building construction & renovation
- Power generation & heating/cooling
- Measuring, regulation & control of energy performance of buildings

In terms of the buildings sector, renovation will go occur in conjunction with the RES4Build system, so EU taxonomy compliance for building renovations is of relevance to the RES4Build.

Substantial contribution

	Construction of new buildings	Renovation of existing
Climate change mitigation	- Primary energy demand 10 % lower than nZEB (nearly Zero Energy Buildings) Buildings > 5000 m2 require a mandatory Life Cycle Assessment	- 30% reduction of Primary Energy Demand

	Construction of new buildings	Renovation of existing
	and Global Warming Potential disclosure Mandatory air-tightness and thermal integrity disclosure.	
Climate Change Adaptation	- Carry out RA and an asset adaption strategy with duty for the operator/owner to implement the adaptation measures identified within 5 years.	- Measures adopted must not increase rates of operational Carbon emissions – exception if demonstrated that increase is necessary and there is a positive trade-off - Renovations designed to meet local/national/regional requirements for 'major renovation' as defined in Energy Performance Buildings Directive (EPBD);
Transition to Circular Economy	- At least 70 % (by weight) of non-hazardous construction and demolition waste (excluding naturally occurring material in category 17 05 04 in the EU waste list) generated on the construction site must be re-used or recycled or similar. - Building designs and construction techniques support circularity and demonstrate (ref to ISO 20887) how they are designed to be more resource efficient, adaptable, flexible and dismantleable to enable reuse and recycling	
Sustainable use and protection of water resources	- Compliance with Appendix B - Water use and protection management plan – proof of water flow rates - Flow rates: tap max 6 l/m, WC cisterbs max vol 6 l and avg flush 3.5 l, Urinals max 2 l/bowl/hr	
Pollution prevention and control	- Compliance with Appendix C - Brownfield sites (potentially contaminated) – must be subject to investigation for potential contaminants. - Reduction of noise, dust, and pollutant emissions during works. - Limit harmful materials – indoor materials emit <0.06 mg formaldehyde / m3	
Biodiversity	- Compliance with Appendix D - Environmental Impact Assessment required by EU law - Mitigation for biodiversity-sensitive areas - Criteria for not building on: arable land and crop land, greenfield land and high biodiversity value, Forest/wooded land	

1.16 iBROAD

The iBRoad project is funded by the Horizon 2020 European programme and aims to lift barriers for building owners, in the form of a lack of knowledge regarding building renovation measures, by developing single-family houses. Essentially, renovation roadmaps will serve as a tool outlining a customised renovation plan with a long-term horizon for deep step-by-step renovation of individual buildings (iBRoad-Plan). Combined with the iBRoad-Plan is a building passport (iBRoad-Log), which includes information on building energy consumption and production, executed maintenance, and building plans.

The project will provide public authorities with real-life studies and analysis supporting the benefits of deep renovation, both as an individual building strategy and as a long-term national strategy. The aim is for the building renovation roadmaps to complement existing EPCs, which inform potential buyers/tenants on a buildings' energy performance.

1.17 European Union (District Heating) Regulations 2022

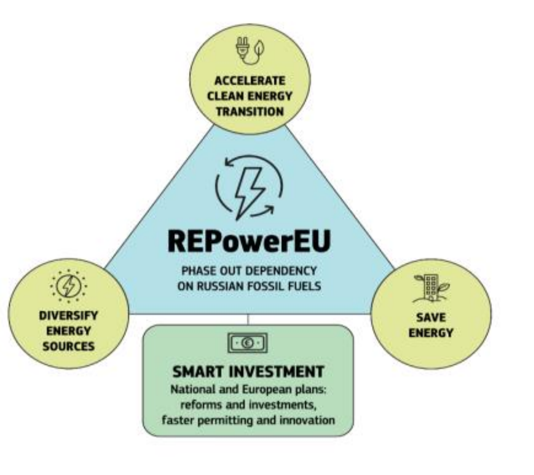
Submissions for a public consultation on the introduction of these regulations is closed as of the 15th of July 2022, regulations are still in draft form.

The reason for the introduction comes after the 2018 amendment of the Directive 2009/28/EC of the European Parliament and of the Council on the promotion of the use of energy from renewable sources (recast), in which EU Member States are required to permit minimum levels of renewable energy in Building Regulations to be fulfilled through efficient district heating and cooling using a significant share of renewable energy and waste heat and cold.

1.18 REPowerEU

A plan to rapidly reduce EU dependence on Russian fossil fuels and fast forward the EU green transition. The REPowerEU plan builds on the Fit for 55 package, and puts forward the additional set of actions to:

- save energy;
- diversify supplies;
- quickly substitute fossil fuels by accelerating Europe's clean energy transition;
- smartly combine investments and reforms.



1.19 F-gas regulations

Fluorinated greenhouse gases (F-gases) are hydrofluorocarbons (HFC), perfluorocarbons (PFC), sulphur hexafluoride (SF6) and other greenhouse gases that contain fluorine or mixtures containing any of those substances. They are used in refrigeration, air-conditioning, insulation foams, electrical equipment and fire extinguishers as well as other things like aerosol sprays, and solvents.

HFCs are the most common and are used in a wide range of applications including commercial and industrial refrigeration, air-conditioning systems, heat pumps, blowing agents for foams, and fire extinguishants. HFCs were developed in the 1990s to substitute CFCs and HCFCs as these have a high ozone depletion potential (ODP).

PFCs are widely used in the electronics, cosmetics, and pharmaceutical industries, as well as in refrigeration when combined with other gases. They were also used as fire extinguishants in the past and are still found in older fire protection systems. SF6 is used in high-voltage switchgear.

The regulatory framework for the use of F-gases as refrigerants has been characterized by the following protocols and directives in the EU.

EU regulation (Nº 517/2014)

The current F-gas regulation, which has been in application since 1 January 2015, replaces the original F-gas Regulation adopted in 2006. This current regulation maintains various measures from the previous F-gas regulation (842/2006) such as leak prevention, recovery, certification of technicians and selected restrictions to the use and marketing of F-gases. However, it also strengthened previous measures in order to reduce the use of these gases and the emissions associated with them. These strengthened measures include:

• Limiting the total amount of the most relevant F-gases that can be sold in the EU from 2015 onwards and progressively phasing them down to one-fifth of 2014 sales in 2030. In 2018, a 37% reduction to their commercialisation was implemented. This will be the main driver of the move towards more climate-friendly technologies.

• Banning the use of F-gases in many new types of equipment where less harmful alternatives are widely available, such as refrigerators in homes or supermarkets, air conditioning units and foams and aerosols.

• Preventing emissions of F-gases from existing equipment by requiring maintenance inspections, adequate servicing and end-of-life gas recovery.

• Ban on F-gas based refrigerants with a GWP higher than 2,500 and refrigeration equipment with a charge size of 40 tons of CO2 eq. or more, which affects large installations.

• Ban on foams that contain HFCs with GWP of 150 or more. Extruded polystyrene-based foams are banned since the 1st of January of 2020. Other foams will be banned on the 1st of January of 2023.

Thanks to the F-gas Regulation, the EU's F-gas emissions are expected to be reduced by two-thirds by 2030 compared with 2014 levels.

MAC Directive

The MAC Directive prohibits the use of F-gases with a global warming potential more than 150 times higher than that of carbon dioxide (CO2) in specific mobile air-conditioning systems of new cars and vans introduced from 2011, and in all new cars and vans produced from 2017 onwards.

Montreal Protocol

The Montreal Protocol is an international environmental agreement that achieved universal ratification. It was originally intended to protect the earth's ozone layer, with the goal of eliminating the use of ozone depleting substances (ODS). However, its scope has been increased to GHG emissions reduction after the implementation of other relevant policies.

Below, a timeline of the different policies implemented based on this protocol are showcased:

• 1987: Created requirements that would begin the worldwide phase-out of ozone depleting CFCs.

• 1992: Schedule to begin the phase-out of HCFCs (HCFCs still contain ozone-destroying chlorine).

• 1996: CFC production in all developed countries was strictly prohibited.

• 2013: Developing countries agreed to start their phase out process in 2013 and are now following a stepwise reduction until the complete phase-out of HCFCs by 2030.

• 2016: HFCs added to the list of controlled substances. Gradual reduction of 80-85% by the late 2040s.

• 2020: Developed countries phased-out HCFCs

The Paris Agreement and Kigali Amendment 2016

The Paris Agreement is a legally binding international agreement on climate change to limit global warming to below 2, preferably 1.5 degrees Celsius, compared to preindustrial levels. It was adopted by 196 Parties at COP21 in Paris on 12 December 2015 and came into force on 4 November 2016.

In addition to this the Parties to the Montreal Protocol reached agreement at their 28th Meeting of the Parties on 15 October 2016 to phase down HFCs, known as the Kigali Amendment.

In this amendment, it was agreed to add HFCs to the list of controlled substances and approved a timeline for their gradual reduction by 80-85% by 2047.

In the figure below, a timetable of the F-gas regulatory framework from 1987 to 2047 is shown, including the adoption of the Kigali amendment in 2018:

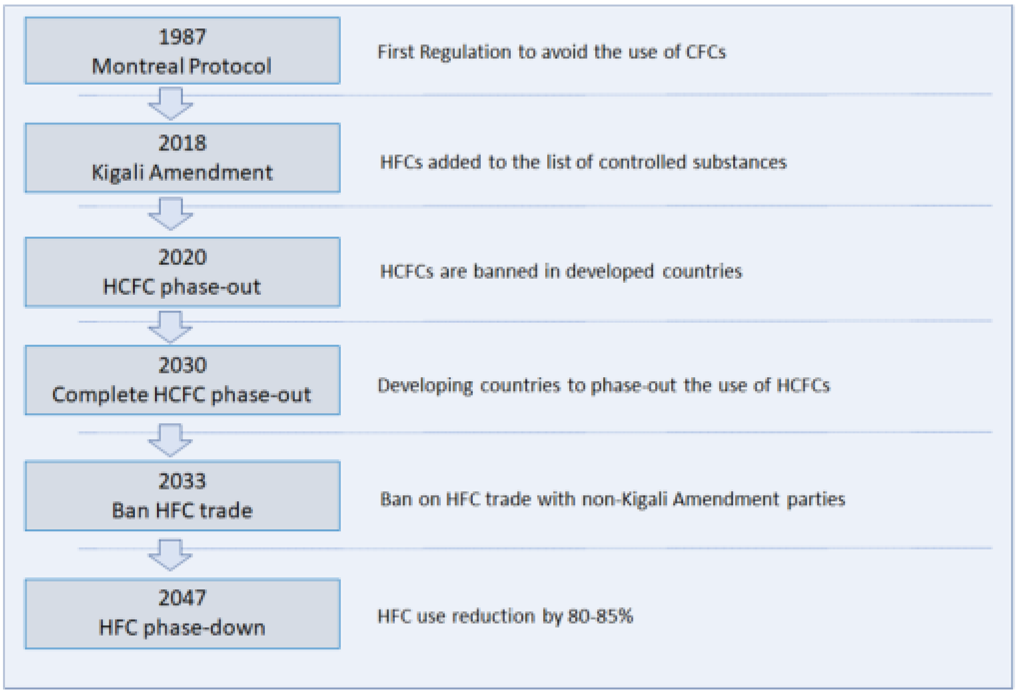


Figure 1-1: F-gas Regulatory Framework Timeline

Update of the EU Fluorinated Gases Regulation 2022

On 5th April 2022, the European Commission published a legislative proposal to review the European F-gas regulation (EU regulation Nº 517/ 2014). In general, this proposal intends to increase the restrictions on the use of F-gases and improve the implementation of the F-gases alternatives.

As a result, it is expected that a total amount of emissions accounting for 40 MtCO2eq by 2030 and 310 MtCO2eq by 2050 will be avoided.

The Regulation update proposes the upcoming prohibitions in the refrigerant industry 26:

• Refrigerators and freezers for commercial use (self-contained equipment) that contain F- gases with GWP of 150 or more; prohibited from 1st January 2024. In addition, any self-contained equipment containing F-gases with GWP of 150 or more will be prohibited from 1st January 2025

• Stationary refrigeration equipment, that contains, or whose functioning relies upon, fluorinated greenhouse gases with GWP of 2 500 or more except equipment intended for application designed to cool products to temperatures below -50ºC; prohibited from 1st January 2024

• Plug-in room and other self-contained air-conditioning and heat pump equipment that contain Fgases with GWP of 150 or more; prohibited from 1st January 2025

• Stationary split air-conditioning and split heat pump equipment:

- Single split systems containing less than 3kg of F-gases, or whose functioning relies upon F gases listed in Annex 1 with GWP of 750 or more; prohibited from 1st January 2025.
- Split systems of a rated capacity of up to and including 12 kW containing, or whose functioning relies upon, F- gases with GWP of 150 or more, except when required to meet safety standard; prohibited from 1st January 2027

- Split systems of a rated capacity of more than 12 kW containing, or whose functioning relies upon, F- gases with GWP of 750 or more, except when required to meet safety standard; prohibited from 1st January 2027

Additionally, this proposal includes upcoming prohibitions for other industries as well such as:

• Foams that contain HFCs with GWP of 150 or more, except when required to meet national safety standards; prohibited from 1st January 2023

• Personal care products (i.e. mousse, creams, foams) containing F-gases; prohibited from 1st January 2024

• Equipment used for cooling the skin that contain, or whose functioning relies upon, F- gases with GWP of 150 or more except when used for medical applications; prohibited from 1st January 2024

• Fire protection equipment that contains or rely on other F-gases listed in Annex I, except when required to meet safety standards; prohibited from 1st January 2024

It should be considered that consultations over these future prohibitions will take place over the next 12-18 months and some prohibition dates may be modified. It is also important to note that, even when the use of F-gases in the refrigeration and other industries will be banned, there will be a considerable period of coexistence between newly installed equipment and the existing one.

The chart below represents the F-gases phase down plan over the next few years in the European Union and outlines the main bans that have been implemented and will be implemented up to 2030 in order to reduce the use of F-gases.

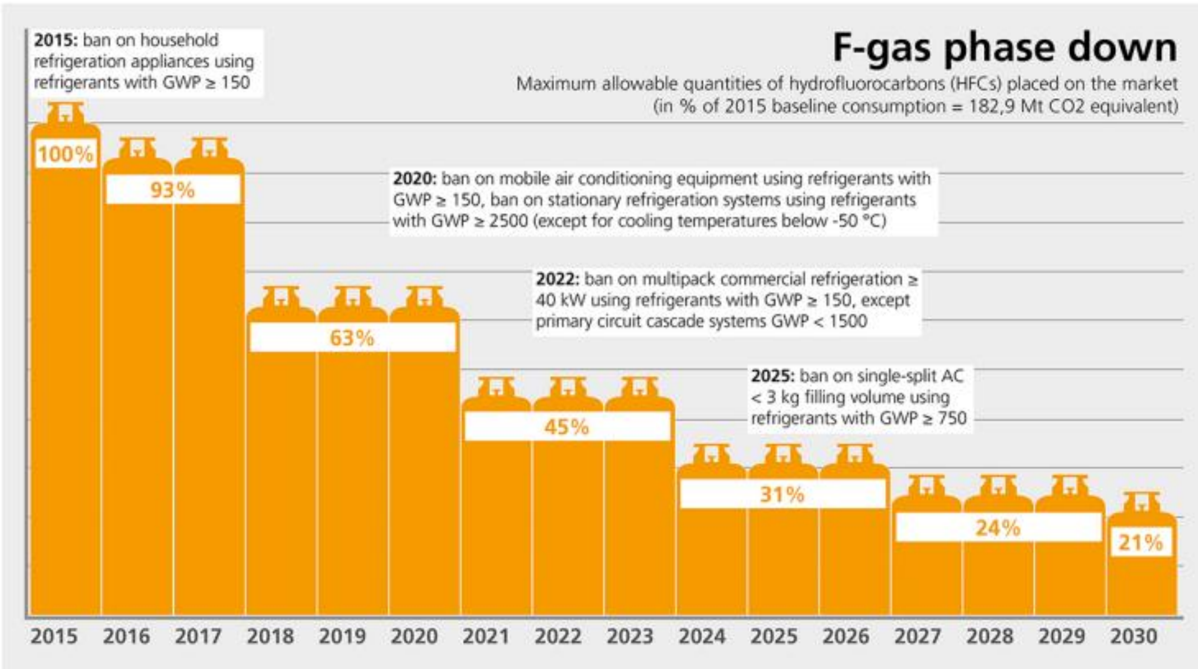


Figure 1-2: F-gases reduction Plan in the EU 27 (Arup)

1.20 UN Sustainable Development Goals

Although the sustainable development goals of the UN are not EU policies, very often EU refers to them. The following goals are relevant to discuss for the case of RES4BUILD:

Goal 7: Affordable and Clean Energy

This goal ensures access to affordable, reliable, sustainable, and modern energy for all and aims to achieve the below targets:

- Target 7.1: By 2030, ensure universal access to affordable, reliable and modern energy services
- Target 7.2: By 2030, increase substantially the share of renewable energy in the global energy mix
- Target 7.3: By 2030, double the global rate of improvement in energy efficiency
- Target 7.a: By 2030, enhance international cooperation to facilitate access to clean energy research and technology, including renewable energy, energy efficiency and advanced and cleaner fossil-fuel technology, and promote investment in energy infrastructure and clean energy technology
- Target 7.b: By 2030, expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries, in particular least developed countries, small island developing States, and land-locked developing countries, in accordance with their respective programs of support

Each target is evaluated based on specific indicators[1].

Goal 11: Sustainable Cities and Communities

This goal is set to make cities and human settlements inclusive, safe, resilient, and sustainable, and aims to achieve the below targets:

- Target 11.1: By 2030, ensure access for all to adequate, safe and affordable housing and basic services and upgrade slums
- Target 11.2: By 2030, provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons
- Target 11.3: By 2030, enhance inclusive and sustainable urbanization and capacity for participatory, integrated and sustainable human settlement planning and management in all countries
- Target 11.4: Strengthen efforts to protect and safeguard the world's cultural and natural heritage
- Target 11.5: By 2030, significantly reduce the number of deaths and the number of people affected and substantially decrease the direct economic losses relative to global gross domestic product caused by disasters, including water-related disasters, with a focus on protecting the poor and people in vulnerable situations
- Target 11.6: By 2030, reduce the adverse per capita environmental impact of cities, including by paying special attention to air quality and municipal and other waste management

[1] Goal 7 | Department of Economic and Social Affairs (un.org)

- Target 11.7: By 2030, provide universal access to safe, inclusive and accessible, green and public spaces, in particular for women and children, older persons and persons with disabilities
- Target 11.a: Support positive economic, social and environmental links between urban, peri-urban and rural areas by strengthening national and regional development planning
- Target 11.b: By 2020, substantially increase the number of cities and human settlements adopting and implementing integrated policies and plans towards inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters, and develop and implement, in line with the Sendai Framework for Disaster Risk Reduction 2015-2030, holistic disaster risk management at all levels
- Target 11.c: Support least developed countries, including through financial and technical assistance, in building sustainable and resilient buildings utilizing local materials

Each target is evaluated based on the determined indicators[2].

Goal 13: Climate Action

The goal is to take urgent action to combat climate change and its impacts and aims to achieve the below targets:

- Target 13.1: Strengthen resilience and adaptive capacity to climate-related hazards and natural disasters in all countries
- Target 13.2: Integrate climate change measures into national policies, strategies and planning
- Target 13.3: Improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning
- Target 13.a: Implement the commitment undertaken by developed-country parties to the United Nations Framework Convention on Climate Change to a goal of mobilizing jointly $100 billion annually by 2020 from all sources to address the needs of developing countries in the context of meaningful mitigation actions and transparency on implementation and fully operationalize the Green Climate Fund through its capitalization as soon as possible
- Target 13.b: Promote mechanisms for raising capacity for effective climate change-related planning and management in least developed countries and small island developing States, including focusing on women, youth and local and marginalized communities

Each target is evaluated based on the determined indicators[3].

[2] Goal 11 | Department of Economic and Social Affairs (un.org)
[3] Goal 13 | Department of Economic and Social Affairs (un.org)

1 Appendix A: Netherlands

1.1 Cultural, economic, and social aspects

The way energy is used in each country is influenced by cultural practices and daily habits such as the way of heating, cooling, washing, etc. Therefore, to reach climate targets, it is essential to understand these routines and how they affect the use of energy (Cordis: EU research results, 2018).

As explained in the Deliverable 2.5 of ENERGISE[4], energy efficiency of the buildings and appliances is the most addressed issue among the national campaign trends in The Netherlands. In this context, the Dutch government and major environmental organizations offer information, support, and guidance, as well as coaching and information campaigns spreading information on energy-efficient behaviors (Jensen et al., 2018).

To encourage people to take energy-efficient measures, the government offers subsidies for implementing energy saving measures at the household level including improvement of roof or floor insulation, use of double-glazing or heat pumps, biomass, wood pellet or solar thermal hearing systems, as well as offering free advice on how to save energy and energy saving kits to support energy consumption reduction. Some examples of such initiatives can be found on the online database of ENERGISE.

1.1.1 Residential

Based on the Deliverable 2.5 of ENERGISE which was published in 2018, Dutch households are not particularly interested in energy-related home renovations compared to households in other countries. The majority is concerned with investment costs (e.g., for home insulation) and consider their heating system to be working sufficiently well (Jensen et al., 2018). However, this trend seems to have changed since then.

The Local Energy Monitor 2021 (HIER climate foundation and RVO, 2022[5]) reports that locally, more and more energy cooperatives (that is partnerships of citizens and local companies that are working on the energy transition in their living environment) and residents' initiatives are working to accelerate the energy transition. In the coming years, steps will be taken by the municipalities to start discussions with various districts on what the future of heat supply will look like in the country. The Local Energy Monitor 2021 reports that the number of residents' initiatives that want to play a role in this process is increasing and that their heating projects are becoming more concrete. There are nearly 150 local heat initiatives on the list, among which 78 are actively involved in detailed heat projects in their neighborhood, or municipality. These initiatives investigate the possibilities for a collective heat supply or collective commissioning for individual homes and are often also involved in the formation of local policies (HIER climate foundation and RVO, 2022). Many of the energy initiatives also provide information and organize activities aimed at raising awareness of the residents.

This change in the pattern of response from people can be seen in various initiatives that are listed on the online database of ENERGISE. For example, the goal for an initiative (Bestaande Wijk van Morgen)

[4] Jensen et al. (2018). *30 national summary briefs of national energy supply and demand*. ENERGISE – European Network for Research, Good Practice and Innovation for Sustainable Energy, Grant Agreement No. 727642, Deliverable 2.5.

[5] HIER climate foundation and RVO. (2022). *Local Energy Monitor 2021*. https://www.hieropgewekt.nl/uploads/inline/Lokale%20Energie%20Monitor%202021_def_digitaal.pdf

was to renovate existing houses from the 70's and bring them to the level of a passive house. One of the challenges though was to convince the tenants to agree to these renovations especially because they had to continue living in the houses as normal during the renovation process. However, this was solved after realization of one demonstration house; the tenants became enthusiastic and (almost) everyone agreed (Initiative: Existing Neighborhood of Tomorrow).

Therefore, it can be concluded that there is an increasing enthusiasm among Dutch households to take sustainability measures and this willingness is growing over time. This can be considered in the strategy of the business plan of Res4Build and stimulated by corresponding solutions.

In the research "Building Future", TNO[6] (2016) reports the following findings:

- many households in The Netherlands heat their home when absent, but at a lower temperature level based on the period that one is not at home.
- more than 10% of households that are not always at home do not heat when they are absent (Leidelmeijer and Cozijnsen, 2009[7]).
- Most households only set the temperature to a very low level in the event of a prolonged absence (12 hours or more).
- especially households with an irregular presence pattern actively adjust the thermostat setting for longer or shorter presence, possibly because manual adjustment of the thermostat is already part of their daily routine (Tigchelaar and Leidelmeijer, 2013[8]).

It has to be noted that the above-mentioned adaptability behaviors are dependent on the type of housing in The Netherlands, as the use of high thermal mass is common in the local construction.

Implemented sustainability measures

Dutch Association for Sustainable Energy (NVDE, 2022) reports that with the high energy prices, the payback period of sustainability measures in 2022 is on average three times shorter than at the beginning of 2021. Depending on the state of the insulation of the house, the following sustainability measures can be implemented:

- In poorly insulated homes, it is best to insulate first. That pays for itself in one to six years, with the new energy prices. The insulation measures can be related to the roof, cavity, floor insulation, and/or HR++ glass (NVDE, 2022[9]).
- In better insulated homes, heat pumps and solar water heaters are suitable options. They pay for themselves in two to six years (NVDE, 2022). Another sustainable heating technique is the use of hybrid heat pump.

Due to the high energy prices, the government is doing a lot to make the investment attractive: with a generous ISDE subsidy (30 percent of the costs); favorable and even interest-free loans; and a shift in energy taxation (electricity tax down, natural gas tax up), sustainability is now particularly attractive.

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[6] TNO. (2016). *Building Future*. TNO. TNO-rapporten Building Future | Rapport | Rijksoverheid.nl

[7] Leidelmeijer, K., and Cozijnsen, E. (RIGO). (2009). *Energiegedrag in de woning. Aanknopingspunten voor de vermindering van het energiegebruik in de woningvoorraad*. RIGO Research en Advies BV, Amsterdam; Publicatie van het voormalig Ministerie van VROM/Wonen Wijk en Integratie (WWI).

[8] Tigchelaar, C., and Leidelmeijer, K. (2013). *Energiebesparing: Een samenspel van woning en bewoner - Analyse van de module Energie WoON 2012*. ECN, Petten.

[9] NVDE. (2022, August 18). *Bewoner verdient isolatie of duurzame warmtetechniek snel terug door hoge energieprijzen*. https://www.nvde.nl/nvdeblogs/bewoner-verdient-isolatie-of-duurzame-warmtetechniek-snel-terug-door-hoge-energieprijzen/

In addition, municipalities have been given the means to take targeted action against energy poverty for people with low incomes (NVDE, 2022).

The government recently announced the standardization of heat installations in homes, which will come into effect from 2026. When replacing, at least a hybrid heat pump must be installed. This will be an economical and cost-effective measure for the households to take. It is important to keep the preconditions in such a way that this also remains profitable and feasible for people, so with adequate subsidies, taxes, loans, and targeted support for low incomes. It is possible that building-related financing can lower that threshold even further. The same approach is also possible for the house itself: for example, by setting minimum insulation requirements for renovation or the sale of the house, as good insulation is the best guarantee to keep the energy demand and therefore the energy bill limited.

The trace of the commonly implemented measures can be seen in the market as well. Many companies in renewable energy are finding it increasingly difficult to keep up with the sharply increased demand for solar panels, insulation, and heat pumps. For example, no less than three out of four companies are confronted with shortages of material (NVDE, 2022[10]). The statistics show that the demand in new construction for both air heat pumps, and ground heat pumps is growing, but the one for air heat pumps is growing faster.

Based on "The Housing Survey Netherlands", published by The Ministry of the Interior and Kingdom Relations (June 2022):

- Replacing the central heating boiler (cv-ketel in Dutch) in both owner-occupied and rental homes is the most implemented sustainability measure.
- Installing or replacing solar panels occurs more often in the owner-occupied sector than in the housing association and private rental sector.

[10] NVDE. (2022, August 12). *Driekwart bedrijven in duurzame energie heeft last van materiaaltekorten*. https://www.nvde.nl/nvdeblogs/driekwart-bedrijven-in-duurzame-energie-heeft-last-van-materiaaltekorten/

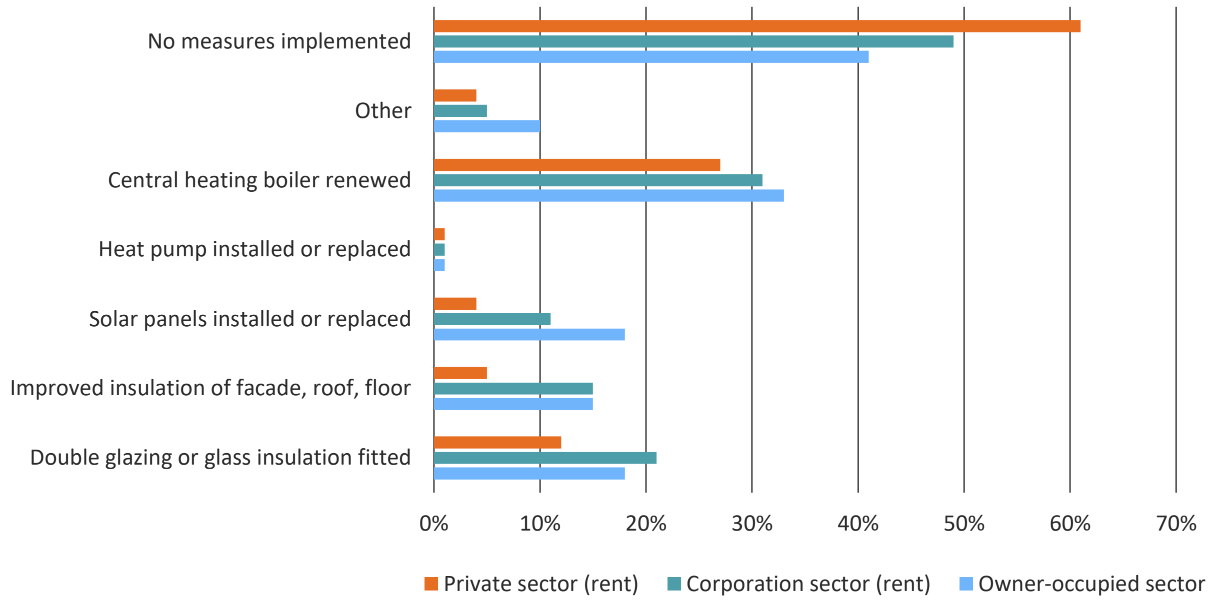

Figure 1-1: Implemented sustainability measures in the past five years to type of property (excluding households with a duration of less than five year); 2021

- Among the owner-occupiers, the renewal of the central heating boiler was mainly done (79%) because this was already necessary for maintenance, while installing and/or replacing solar panels was mainly done because the investment pays for itself in a lower energy bill (71%). Improving the insulation of floor, roof, facade, or the type of glass was mainly done to make the home more pleasant, and also due to necessary maintenance.
- Among all income groups, the most frequently mentioned reason for taking energy-saving measures is that this was already necessary for maintenance. This reason is more the concern of owner-occupiers with the lowest incomes than by the ones with the highest incomes.
- Among owner-occupiers with the highest incomes, the main reason for taking energy-saving measures is because of the environment. This is considerably higher than among the lowest incomes.
- Among all income groups, the most frequently mentioned reason for not making the home more sustainable is that the home was already energy efficient. This is mentioned more often among the highest incomes than among the lowest incomes, which show that the highest incomes generally have better insulated homes than the lowest incomes.
- The willingness to take sustainability measures in the future differs greatly between income groups. Among owner-occupiers with the lowest incomes, 35% are prepared to take measures in the future, compared to 74% among the highest incomes.
- Among different age groups, the share that wants to take sustainability measures in the future is considerably lower among the elderly singles than among young singles. Couples are slightly more likely to take measures in the future than single people, but further analysis shows that this is because couples have a higher income on average than single people.
- It is likely that owner-occupiers in newer homes think more often about installing a heat pump or (more) solar panels, while those in older homes more often want to insulate their home even (better) afterwards.

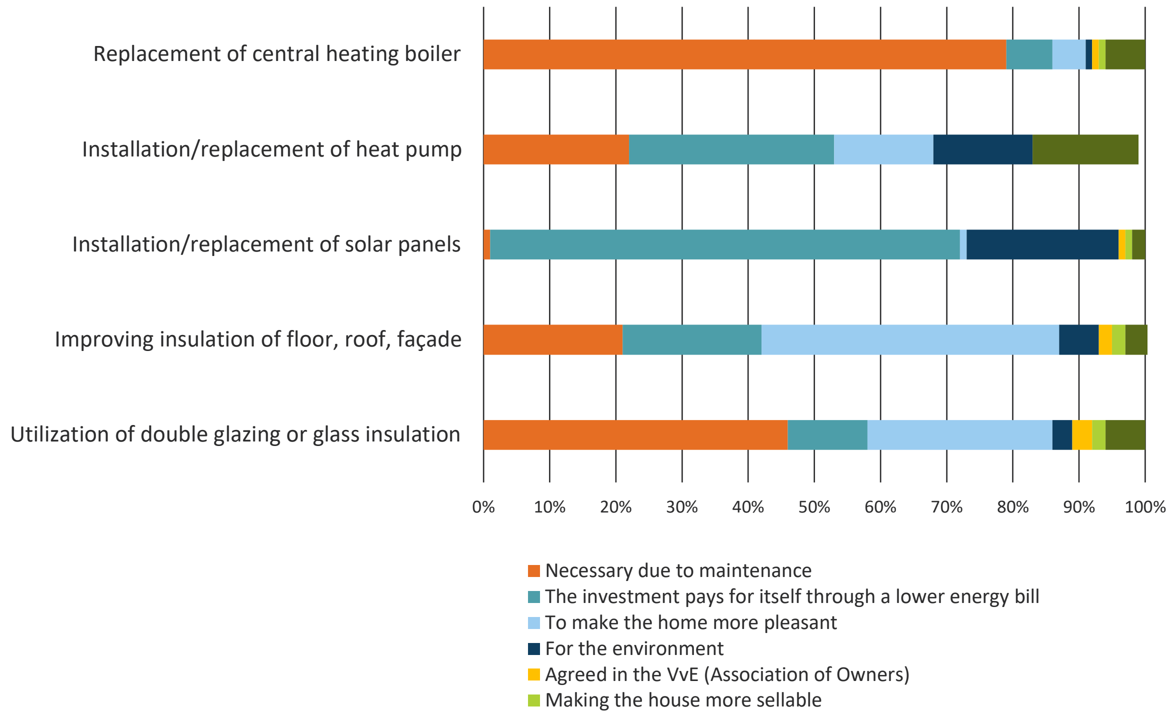

Figure 1-2: Main reason for owner-occupiers to implement sustainability measures by type of measure (excluding households where several sustainability measures have been implemented); 2021

1.1.2 Offices

According to the website of Dutch Green Building Council (DGBC), the Dutch office market has a very low need for expansion and there is not a lot of construction to be done. Due to the new way of working and the economic crisis during 2008-2014, it has been revealed that the Netherlands had a clear oversupply on the office market. This amount has been reduced almost in half, by transforming the vacant offices into predominantly living spaces. The need for expansion is therefore low and limited to economic growth markets where there is not enough office space to facilitate economic growth. It can be concluded that the sustainability ambition within the office sector must be achieved almost entirely in the existing buildings and the opportunities therefore lie entirely in (large-scale) renovations of the existing built office environment (DGBC).

To achieve sustainability ambitions in the Dutch office market, the following aspects must be considered as the background of the market:

- **Ownership of an office:** Either the office is used by the owner, or it is leased by the owner to third parties. An owner/user does not have to take a tenant into account when making a sustainability assessment and earns back the investment directly through lower energy costs. A landlord often runs into the split incentive, the tenant benefits from the lower energy costs while the landlord makes the investments for this purpose (DGBC).
- **The investment time horizon** differs per investor within the office sector. On average, private equity parties have an investment time horizon of approximately 2 to 5 years before the building in question is sold again. While institutional investors are much more likely to purchase a building for a long-term operation of at least 10-15 years. For a possible sustainability decision, this is particularly important in relation to the payback period and the discussion about the value effect of a sustainability investment (DGBC).

- **Location of the office (to which municipality it is related):** Promoting sustainability ambitions is expected to be more difficult in areas where there is a structural oversupply in the office market. A competitive advantage can be gained in these markets if sustainability is implemented, but it also means that it is more difficult to make some of the stock more sustainable because there is insufficient structural market demand to recoup a sustainability investment. In addition, we see the opposite picture in locations where there is a lot of market shortage. It can be seen there that sustainability plays even less of a role there, because companies have fewer options in their accommodation. As a result, scarcity of office space can sometimes also contribute to a more limited need to become more sustainable. The prevailing thought is that, even without further sustainability features, the office will still be rented out (DGBC).

  There is an opposite trend as well. For the construction of new buildings in dense urban areas and top business locations, investors and developers want their building to stand out compared to the competitors in the field in terms of sustainability aspects. To achieve that, they are willing to implement stronger sustainability measures such as aiming for BREEAM outstanding or excellent. In case of renting to a third party, the developers and owners also consider the responsibility of the tenant regarding the sustainability measures, for example by drawing up a Green Lease agreement. This is a legally binding lease agreement between the developer and the tenant which require tenants to use a fit-out guide with mandatory BREEAM requirements (BREEAM Knowledge Base).

For offices, there are guidelines on which measures are for the owner and which measures are for the user of the building. In both single and multitenant situations since 1 July 2019, users are required to report on the implementation of these measures. Furthermore, the EED (Energy Efficiency Directive) may apply to large companies and organizations. The EED calls for energy saving plans to be drawn up.

Higher rental income for certified offices

CBRE's EMEA sustainability report shows that office buildings that meet Environmental, Social and Governance (ESG) standards through sustainability certification have higher rental income than office buildings that do not meet ESG standards. In Amsterdam, certified buildings have an average of 27% higher rent compared to non-certified buildings.

The rent premium is largely driven by benefits associated with sustainable buildings, including lower operating costs, better corporate reputation and greater comfort, well-being, and productivity of the residents. These benefits can be redeemed in rental value. The findings also point to the significant potential for a "*brown discount*[11]" for buildings with relatively weaker sustainability performance (CBRE, 2021).

The research by CBRE shows that companies seem to consider certifications to a greater extent. Even though the location is still the main decisive factor in choosing the location, there are more and more companies that give sustainability factors higher priority in this decision-making process. This trend not only affects the number of certified firms, but there now also seems to be clear international evidence that firms with a sustainability certification operate better and, in the long term, should have a value-driving effect (CBRE, 2021).

[11] Potential for obsolescence, also known as the brown discount, for existing buildings that do not "green up": Just as green buildings that outperform the market may show a value premium, brown buildings that underperform relative to their market may show a discount. Source: Green Energy

CBRE expects ESG to play an increasingly leading role in business and, as a result, the demand for certified firms will increase. The fact that 1 in 5 offices in Amsterdam is certified indicates that owners can still create a certain qualitative scarcity. CBRE expects that in the future the vacancy gap will therefore increase further and become more visible on the investment market (CBRE, 2021).

In the Netherlands, BREEAM-NL is the most used certificate to evaluate the sustainability of buildings.

oneCurrent energy labels

Currently, not the entire office stock is provided with an energy label. Eib (Economic Institute for Construction) has extended these labels to the entire stock. The figure below shows the distribution. 30% of the office stock has label A or better. About half of the stock has a green label (C or better) and thus meets the energy label obligation of 2023 (DGBC) (As of 1 January 2023, offices are required to have a valid minimum energy label C).

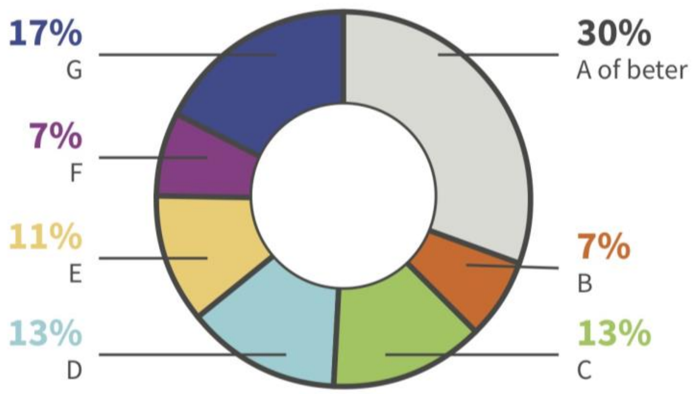

Figure 1-3: Distribution of energy labels by m2 office stock, in percentage. Source: EIB

Split incentive

Published in the report by RVO (2021), one of the obstacles of the Dutch sustainability market is the so-called 'split incentive'. Split incentive means that the investments and the resulting benefits are not evenly distributed between the parties involved. This hinders investment decisions. In traditional leases, the building owner is responsible for maintenance and investments in the building and the building installations. This means that installing more sustainable installations, such as a heat pump or solar panels, is the responsibility of the owner. The tenant pays the energy bill. In the case of the heat pump or solar panels, the tenant has the advantage of this in the form of a lower energy bill. Because building owners in this case do not derive any (financial) benefit from making their buildings more sustainable, they are less inclined to actually implement these measures (RVO, 2021).

Implemented sustainability measures

In the report published by the Foundation of Economic Institute for Construction (Stichting Economisch Instituut voor de Bouw in Dutch) (2020), the following measures are commonly taken in the renovation and transition of office buildings:

- Transition to a completely gas-free office building

- Ground energy is used for heating and cooling, for which a heat and cold storage system has been installed in combination with a heat pump.
- Improving the building insulation
- Equipping the building with solar panels
- Changing the fluorescent lighting to LED lighting
- Utilization of demand-driven ventilation
- Use of intelligent building management systems and energy monitoring systems
- Minimizing the use of hot water
- Use of triple glazing

In some of the presented cases in the mentioned report (Stichting Economisch Instituut voor de Bouw in Dutch, 2020), the following measures are also taken during the renovation process, which might be more project specific:

- Transition from high-temperature heating to low-temperature heating and from low-temperature cooling to high-temperature cooling
- Use of the existing ground storage (ATES) is optimized, and the use of district heating and district cooling is minimized.
- The central ICT is migrated to a virtual environment and the energy consumption on workplace equipment is minimized.
- Climate facades have been installed that make smart use of daylight, solar heat, and ventilation to control the indoor climate.
- In addition to the technical measures that have been taken, policy adjustments have also been made that have resulted in energy savings (such as Archimedeslaan 10 building in Utrecht).

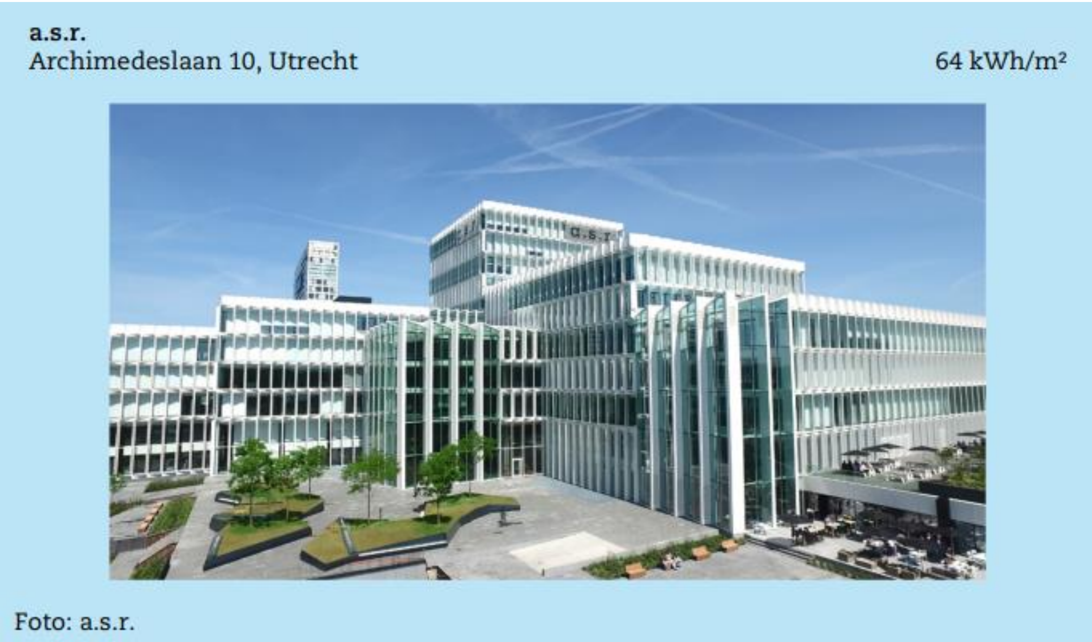

Figure 1-4: Office building Archimedeslaan 10, Utrecht. Source: EIB, 2020

1.1.3 Public

In the Knowledge and Innovation Platform for Making Social Real Estate More Sustainable (KIP MV), organizations from the healthcare, sports, monuments, museums, education, and municipalities join forces. Within the platform, they exchange knowledge, share good examples and drive innovations. In this way, they can facilitate and support buildings within their social sector in making buildings more sustainable (Knowledge and Information Platform).

Many municipalities in the Netherlands have already started working on making their real estate more sustainable. Apart from renting out buildings that are more sustainable, they also have a social role to set a good example.

Based on a few public buildings presented in the report "*Making the office stock more sustainable: An exploration of future energetic performance in different scenarios*" (Stichting Economisch Instituut voor de Bouw, 2020), it can be concluded that the following sustainability measures are commonly taken in the renovation processes or transition of the public buildings to a more sustainable one:

- The transition to a completely gas-free building
- Use of heat pumps
- Use of hot and cold storage systems for heating and cooling
- Improvement of the building insulation to facilitate low temperatures
- Implementing intelligent building management systems and energy monitoring systems
- Equipping the building with triple glazing or double glazing where possible
- Equipping the building with LED lighting and solar panels
- In some buildings, demand-based ventilation is applied using smart CO_2 control

1.1.3.1 Education

Of all Dutch classrooms, it appears that 70 to 80 percent do not meet the minimum requirements for the indoor environment, according to figures from the Netherlands Enterprise Agency (RVO). Common problems are low air quality and ventilation, too low temperatures, and draft complaints in the winter, overheating in the summer and problems with daylight and lighting.

Many schools in the Netherlands have taken sustainability steps. The practical experiences have been gathered and published on the website of "*Schools on course for 2030*". The following approaches seem to be in common among them:

- Transition to natural gas-free schools
- Installation of heat pumps, sometimes by using the generated electricity by the solar panels on the roofs
- Taking energy saving measures not only for sustainability but also for economic reasons
- Implementation of online monitoring to smartly control the cost of installations
- Renovation of schools, small- or large-scale
- Use of heat and cold storage in the ground
- Improving the insulation of the building envelope
- Generating energy by using solar panels
- Better ventilation systems
- Improvement of heating and cooling systems, such as using low-temperature heating
- Use of Building Management Systems (BMS) to manage the energy usage
- Holding educational sessions to involve the students in sustainability
- Change of fluorescent lighting to LED
- Optimization of heating profiles

As for the obstacles and challenges of this process, these aspects seem to be in common:

- Many municipalities have worked with the school boards to draw up Integrated Housing Plans (IHPs). There have been however some challenges during the process, such as a supporting financial framework. In some cases, this has been solved by linking the IHPs to the regulations. The IHP and the financial agreements made therein have thus acquired a legal basis and function together (*Schools on course for 2030*).

- It costs the municipality about twice as much money to replace or renovate a school building with a natural gas-free energy-neutral building than the government contributes.

1.1.3.2 Healthcare

The Expertise Centre for Sustainable Care (EVZ) offers support to healthcare institutions in drawing up portfolio route maps. The center has examples, calculation tools and a knowledge base with publications on various sustainability measures. The EVZ is part of the Knowledge and Innovation Platform for making social real estate more sustainable (Making buildings more sustainable - Care (rvo.nl)).

Healthcare is responsible for 7% of the total annual Dutch CO_2 emissions (Sustainable care for a healthy future | Green deals). To accelerate sustainability in healthcare, 54 parties signed the Green Deal 'The Netherlands on the road to Sustainable Care' on 27 October 2015. After three years, substantial steps were taken in the systematic sustainability of healthcare. More than 150 parties, most of them healthcare institutions, are connected. Dozens of healthcare administrators have been informed through the Green Deal and have become involved in the theme of sustainability. Some 20 individual hospitals and healthcare institutions have also taken up the challenge for the Environmental Thermometer quality mark.

The healthcare buildings can be as categorized into two groups:

- Healthcare cure: buildings in which people are treated, including hospitals and primary care such as the general practitioner, dentist, and physiotherapist
- Healthcare care: buildings in which people are cared for (for a long time) (vandv, disabled care, mental health care) (RVO, 2022).

The Green Deal care is also aimed at increasing knowledge. This is done in working groups around themes such as energy, purchasing, food and medicine residues in wastewater. For example, the Energy working group organized an EnergyTrek in which three institutions were helped to become more sustainable. The working group on the future agenda has drawn up the care of the future as a beckoning perspective.

In the Deliverable 4.2, JIN has published five main challenges for the healthcare sector becoming more sustainable. All these challenges are relevant both at the level of the building portfolio as well as the case study level (i.e., individual building or group of buildings) and include:

- Technology
  - Technology options and solutions
  - Measuring/ monitoring buildings and energy
- Finance
  - Funding/finance for refurbishments
- Social
  - End-user requirements and challenges
  - Internal organization Visio and link with external partners/factors

1.2 Building codes and regulations

1.2.1 Residential

In the Dutch residential market, there are various policies which target different audience groups and vary in the scale of application. The audience groups include building professionals, housing associations, social housing corporations, landlords, owner-occupiers, retailers, tenants, and the general public. An overview of only ongoing measures and policies are presented on the MURE Database. While some do not have an ending date, seven of these measures (24 household-related measures in total) will come to an end in 2022, 2023, or 2030.

The policies have different levels of impact, varying from low to high. This impact is defined as the following on the MURE Database: "*For all measures, i.e., both for measures with quantitative evaluations available and for measure without a quantitative evaluation available, a semi-quantitative expert judgement is given, distinguishing between three impact levels: low, medium, and high. These levels are defined as follows (in each case in % of the overall electricity or final energy consumption of the respective sector; in case of fuel substitution and CHP: of primary energy consumption): − low impact: <0.1% − medium impact: 0.1 to <0.5% − high impact: ≥0.5%)*". Most of the policies focus only on a specific aspect; for example, heat distribution and hot water systems, improvement of heating installations/insulations, and roof-, window-, or façade insulations. These incentives have a low or medium impact level. The policies with a high impact level are the ones which have a more integrated approach (relatively) compared to the rest of the incentives. Out of the 24 household-related measures, only 3 have a high impact level, namely "*Change in the Home Valuation System*", "*Energy Performance Standards (Energie Prestatie Norm, EPN)*", "*The Building Decree (2002, 2012 onwards)*". These ones do not have an end date. Here the lack of more incentives with an integrated approach is evident.

The scale of application is relatively broad. For example, some policies focus on the block/neighborhood scale, in which mostly the aim is to make the neighborhood free of natural gas. Other incentives for example, focus on the product level which includes replacement, renovation, or improvement of a specific product type, such as replacement of a boiler with a heat pump or improving the insulation levels of the building envelope. Households and small commercial users can apply for an allowance for the purchase of heat pumps, biomass boilers, solar water heaters, pellet stoves and small wood-fired boilers. Therefore, the targeted end use or product is diverse.

Some of the national policies and measures are as followed:

- Heat distribution law (Warmtewet)
- Change in the Home Valuation System
- Energy Performance Fee Bill (EPV)
- EIA (Energy Investment Allowance)
- Energy performance standards (Energie Prestatie Norm, EPN)
- Mandatory reporting on taken energy savings measures (Informatieplicht)

From 2026, hybrid heat pumps will become the standard for heating homes. Therefore, when replacing a boiler, installing a hybrid heat pump will be mandatory. If a house is not suitable for a hybrid heat pump, an electrical heat pump or a connection to the heat grid can be an alternative (Netherlands Enterprise Agency, 2022). The government offers a subsidy (subsidy for sustainable energy and energy saving for owner-occupied homes (ISDE)) to buy a heat pump. The Heat Fund uses an interest rate of 0% for low and middle incomes. With a subsidy under the ISDE, the user can insulate the house, or buy a solar water heater or electric water heater (Government of the Netherlands, 2022). This policy targets suppliers of heat pumps, installers (fitters), and owners of homes and buildings.

To stimulate the use of solar energy, the government has introduced incentives to promote this technology since the use of solar energy is still expensive. This includes tax return on the energy tax, and investment grant schemes (Government of the Netherlands).

1.2.2 Offices

In total, there are 8 policies related to office buildings on the platform of MURE Database, among which two have a high level of impact. Two of the policies come to an end in 2030. As part of the mandatory standards for the energy performance of utility buildings in The Netherlands, offices are required to have a valid minimum energy label C as of 1 January 2023. If this requirement is not met, the building may no longer be used. This policy has a high impact level (MURE Database). If an office wants to achieve an Energy Label C, building-related energy-saving measures for heating, insulation, lighting, and ventilation must be implemented. An important point of attention remains an efficient management and maintenance (RVO, 2022).

To support the transition and improvements of the office buildings toward a minimum energy label C, there are financial arrangements and subsidies provided by the government. The municipality where the office is located, is the enforcer for this transition and acts in the event of a violation of the energy label C obligation.

As from July 2019, companies need to report on which energy savings measures they have implemented. They must continue to do so every four years.

Energy labels versus measuring on actual consumption

The Delta Plan for Sustainable Renovation, an initiative of the Dutch Green Building Council (DGBC), was launched in 2017 to accelerate the sustainability of existing buildings. At the time, the current label C obligation and label A obligation as of 2030 was discussed. DGBC and its partners asked themselves whether label A should be the final requirement; does a building thus meet the Paris climate goals and is it Paris Proof? (DGBC). It was concluded that the energy labels do not say anything about the emissions of the building and do not appear to be a good indicator of actual consumption, especially for energy-efficient buildings, according to studies of ECN offices.

The ambition of Delta Plan for Sustainable Renovation is to make the built environment Paris-proof as early as 2040. That is why DGBC has set a Paris Proof number or a “final standard”, for each sector, to work towards being carbon neutrality. There is a specific standard regarding the maximum energy consumption per square meter per year, depending on the sector and building type. The value of 70 kWh/m² per year for offices is now established. This value is equivalent to 'on the meter' or from the energy bill (DGBC).

The elaboration of the Target for 2030 and the Final Standard for 2050 from the Climate Agreement are based on theoretical consumption from the NTA8800 standard. DGBC advocates an alternative route through actual consumption to comply with legislation, starting with ambitious buildings and portfolios that significantly outperform the intended theoretical values and for which it can be stated with certainty that the safety net of minimum energy labels (at offices), EED and Recognized Measures has been met. Until 2020, this alternative route for the sectors consisted of the Long-Term Agreements (MJA).

In response to market demands, DGBC will draw up more guidelines for calculating consumption per square meter, and how to deal with special items such as charging points and data centers. There is also a need for ambition levels and appreciation for buildings 'on the way to Paris Proof'. This determination method will be done in collaboration with TVVL, an organization that has previously drawn up the similar WENG protocol (DGBC).

Delta Plan for Sustainable Renovation

The Paris Climate Agreement of December 2015 prompted the Dutch Green Building Council to develop a Delta Plan for Sustainable Renovation for non-residential buildings and homes. It is a multi-year sustainability program for the utility; not only commercial real estate (offices, retail, and logistics), but also social real estate, including schools and healthcare. The existing non-residential construction is a sector that is not yet well represented in Dutch energy policy, while it accounts for a third of the CO_2 in the built environment (DGBC).

Split incentive

How the current market is organized in the field of contracts and finances still brings several financial obstacles, with questions such as: who is going to pay for this? The owner who owns the building but does not pay the utility bill? Or the tenant who benefits from the lower energy bill? (DGBC).

Sometimes there is a split incentive. The interests between the landlord and the user/tenant of a building differ. For example, a landlord invests in energy saving measures, but the user of the building benefits from the lower energy costs (RVO, 2022).

In addition to the property value, an investment for one owner is interesting when the rent can be increased. This is justified, because the tenant with a sustainable building will have a lower energy bill and, for example, a higher comfort with less absenteeism due to illness. The total costs can then remain the same, or possibly even be lower. Nevertheless, this principle often proves difficult in practice and there remains a 'split incentive' between tenant and landlord. A lot of work has already been done in the past to bridge the split incentive, including through the Sustainable Housing Platform, via green lease, all-in hiring and ESCo contracts. At the start of the Offices working group, in which the management of a total energy consumption was proposed, this was partly done to break the split incentive. By making the owner responsible for the total consumption, and renting out the building all-inclusive, he also has the incentives to address and guide the tenants. This development is growing partly because the share of collection and flex offices is growing (DGBC).

From split incentive to shared incentive

Investments in sustainability and the resulting benefits are often not evenly divided between the parties involved, such as the owner and the tenant. As a result, investment decisions are difficult. As opposed to split incentive (different motives), there are shared incentives (joint motives) which propose a more equal distribution of the profits among the parties involved. There are example projects of organizations that have successfully joined into the collaboration. The examples are about commercial real estate and social real estate such as a theater / community center and a municipal recycling center (RVO, 2022). It would be useful to assess whether the practical implementation of shared incentives into the current policies would be possible, and if so, how this could be accelerated.

Wetchecker energy saving (online tool)

Using the *Wetchecker energy saving* online tool allows for checking which legal obligations there are for the owner of a company and how to comply with them. By answering the questions on the website, the results will be provided. To answer the questions, the following information is needed:

- environmental permit (function per location)
- energy bills, broken down into electricity and natural gas consumption and/or natural gas equivalents
- financial statements
- number of employees

- building area of all buildings and usable area of the office function.

Green Projects Scheme

People who want to invest in environmentally friendly projects in the Netherlands can request a *'green financing'* loan from their bank. The interest on this loan is lower than what would normally be paid. The Green Projects Scheme (*Regeling Groenprojecten*) stimulates new developments in environmental technology, circular economy, and durable and innovative (construction) projects (RVO).

Green banks and green funds can apply for a green declaration with the Green Projects Regulation. With such a green declaration, they can finance sustainable projects of their customers at a lower interest rate. Various banks and investment institutions have a green fund. Savers and investors put money into this and thus benefit from a tax benefit (RVO).

The following activities are eligible for benefits from the Green Projects Scheme:

- to invest or save in an eco-friendly manner in the Netherlands
- to invest in a project eligible for a Green Declaration (Groenverklaring): Eligible projects are listed in seven categories, among which three categories are relevant to the case of RES4BUILD:
    - Renewable energy
        1. For generation of renewable energy
        2. For storage and distribution of renewable energy
        3. For efficient use of energy
    - Sustainable construction
        1. For new construction of dwellings
        2. Redevelopment
        3. Renovation of dwellings
        4. New construction of non-residential buildings
        5. Renovation of non-residential buildings
    - Climate adaptation
        1. Retention area
        2. Building- and site-related water storage
        3. Innovative cooling of buildings
        4. Vegetation roofs
        5. Groundwater in peat meadows

(Government information for entrepreneurs).

Activities Decree buildings (Activiteitenbesluit gebouwen)

The Environmental Management Activities Decree obliges companies and institutions (establishments) to take energy-saving measures with a payback period of 5 years or less. This applies to companies and institutions that consume more than 50,000 kWh of electricity or 25,000 m^3 of natural gas (equivalent) per year. There is a Recognized List of Energy Saving Measures (EML) for the office sector (RVO, 2022).

EED Energy Audit

The EED Energy Audit is an obligation arising from the European Energy Efficiency Directive (EED). Its purpose is to make companies and institutions aware of their energy consumption and of the possibilities to save energy and make it more sustainable. The energy audit provides a detailed overview of all energy flows within the company. The audit also provides insight into the possible savings measures and the expected effects thereof. This includes the energy consumption of buildings, industrial processes, and installations, including transport and heat. Auditable companies must carry out an energy audit every 4 years (RVO, 2022).

System requirements for technical building systems

The revised European Energy Performance of Buildings Directive (EPBD III) prescribes system requirements for improving the energy performance of technical building systems. These requirements focus on the energy performance, the adequate dimensioning, installation and adjustment, and the adjustability of technical building systems. The directive was implemented in Dutch laws and regulations on 10 March 2020. From this date, the regulation and requirements must be met. The energy performance requirements applicable to technical building systems are expressed in the calculated primary fossil energy in relation to the net requirement. As a result, not only the efficiency of a technical building system is valued, but also the use of renewable energy. A digital calculation tool has been developed for this purpose (RVO, 2022).

To make the energy performance of buildings more efficient, the committee drew up system requirements for improving the energy performance of technical building systems (RVO, 2022). The system requirements apply to systems for:

- space heating and space cooling
- ventilation
- hot tap water
- built-in lighting
- building automation and control systems: Non-residential buildings with heating or air-conditioning systems with an output of more than 290 kW must be equipped with a building automation and control system (GACS) from 2026. These systems shall be capable of:
  - continuously monitor, monitor, analyze and adjust energy consumption.
  - test the energy efficiency of the building, detect efficiency losses of technical building systems, and inform the manager of the facilities or technical installations of the possibilities to improve this.
  - enable communication with connected technical building systems and other devices in the building. The systems should also be interoperable with technical building systems of different types of proprietary technologies, devices, and manufacturers (RVO, 2022).

The system requirements apply:

- if a new technical building system is installed;
- if, in the case of existing systems, the generator or the ventilation unit (e.g. the central heating boiler, central air conditioner, hot water appliance or ventilation unit) or one third of the delivery bodies or recessed luminaires is installed, replaced or improved.

The EPBD III requires that the energy performance of technical building systems be checked and documented if they are newly installed, replaced or improved. The installer must provide the documentation to the building owner (RVO, 2022).

Technical inspections of heating and air conditioning systems

If a heating and air conditioning system has a heat output or cooling capacity of 70 kW or more, then certain inspection obligations also apply to these systems. If one of the two systems is linked to a ventilation system, this ventilation system must also be inspected. In addition, the heating inspection applies to all heating systems and not only to combustion plants (RVO, 2022).

Charging infrastructure for electric transport

The (private) built environment is obliged to build charging infrastructure for electric vehicles in new construction. This also applies if major renovations are carried out. This obligation is laid down in the Building Decree and must be considered when developing building plans. In addition, there is an obligation to build charging infrastructure for existing larger buildings, even if they are not being renovated (RVO, 2022).

Smart Readiness Indicator (SRI)

The Smart Readiness Indicator (SRI) is an addition to the European Directive on the Energy Performance of Buildings (EPBD) that allows for mapping out the extent to which buildings are suitable for smart applications (European Commission). The SRI rates the smart readiness of buildings (or building units) in their capability to perform 3 key functionalities:

- optimize energy efficiency and overall in-use performance
- adapt their operation to the needs of the occupant
- adapt to signals from the grid (for example energy flexibility)

Energy Registration and Monitoring System (EBS)

The Environmental Management Activities Decree obliges companies and institutions to take energy-saving measures. This is the so-called energy saving obligation. The EBS is one of the measures of this duty. With an energy registration and monitoring system (EBS), it is ensured that the climate installation works as efficiently as possible and has the least energy waste. Since 1 January 2018, the EBS is listed in the recognized list of measures for the office sector (RVO, 2021).

The EBS consists of smart meters and activities. The obligation also means that an annual report on the functioning of the climate installation should be made, the data must be analyzed, and the settings should be adjusted if necessary. This way, the climate system works as efficiently as possible. The report is proof to the competent authority (municipalities and environmental service) that the building complies with the EBS obligation. Various EBS tools are available in the market which help to create an EBS report based on the provided data by the user (RVO, 2021). There are roughly 2 categories:

- online EBS tools
- energy management systems (optimizers)

In the case of change of function

As discussed in section A.1.2, the oversupply in the office market in The Netherlands is evident. Half of the vacant offices have been transformed into living spaces. This change of function is becoming more common as there is also shortage in the housing stock. With this background, it is relevant to discuss change of function from/to an office building.

From a legal point of view, the modification of a user function does not affect the validity of an energy label. A label is valid for 10 years, despite a change in function. This means that when a building is labelled in the past and then becomes an office, the energy label remains valid. The user is free to have a new label for the new function drawn up and registered. This is also advisable in the context of a possible sale or rental of the changed space, so that the energy label matches the new function use. When registering a new label, the old label expires, and the new label is valid for another 10 years. In the event of a change of function to an office function after 1 January 2023, there must of course be a valid minimum energy label C to be allowed to use the office building (The Living Environment Information Point (IPLO)).

Sectoral roadmap: Energy scenarios to 2050

The Sectoral Roadmap Offices explores the sectoral objectives for energy saving and emission reduction, which are then elaborated at building and portfolio level. Sectoral Roadmaps are drawn up for and by all sectors in non-residential construction. Roadmaps for social sectors are already in place or are currently being developed. All Sectoral Roadmaps have four scenarios up to 2050. First, the business-as-usual scenario. In addition, there are three more scenarios up to 2050, which should lead to 30%, 50% and 80% energy savings respectively (with a bandwidth of + and - 5%).

The Foundation of Economic Institute for Construction (2020) has drawn up energy six scenarios[12] for office buildings:

1. Autonomous Scenario: Gas infrastructure remains. Unchanged policy regarding the label C for offices. The basic principle is that part of the market will move forward on its own. Replacement of new construction will be according to BENG. Ultimately, two thirds of the market will be label A by 2050.
2. Sharpened Autonomous Scenario: Label B in 2030 and A+ in 2050. Natural gas still used.
3. 30% scenario: Gasless with air-water heat pumps, new construction with heat and cold storage. On average, better label than the autonomous scenario throughout the stock, among other things due to insulation, heat recovery and installation of PV. At least label B in 2030 and label A+ in 2050.
4. 50% scenario: Gasless with air-water heat pumps, insulation to Rc=3.5[13] m^2K/W, HR++ glazing.
5. 80% scenario: Gasless with water-water heat pumps. Application of heat and cold storage at one third of the stock. Further insulation up to Rc=6 [14]m^2K/W, triple glass, and maximum application of PV on roofs. The 80% scenario is Paris Proof.
6. Hybrid scenario: Gas only for peak times. No adjustment of the emission system and only additional roof insulation (Rc=3.5 m^2K/W) and HR++ glazing compared to the autonomous scenario.

1.2.3 Public

As part of the mandatory standards for the energy performance of utility buildings in the Netherlands, public buildings, health sector, and education sector are required to have a minimum energy label C by 2023. This policy has a high impact level.

However, as discussed in A.2.2, energy labels are not a good indicator of the emissions of a building and whether they comply with the Paris climate goals. Instead, the actual energy consumption should be assessed. For each sector among the public buildings, DGBC has established a Paris-proof number for the maximum energy consumption per square meter per year (DGBC). These are as the following:

1.2.3.1 Education

- Primary and secondary education: 60 kWh per m^2
- Colleges and universities: 70 kWh per m^2

[12] This report was published in 2020 and since then, the basic requirements in the Dutch Building Decree have changed. There is not an updated version published yet. New base values are included in the related footnotes.
[13] New base value according to the Building Decree: Rc=3.7 m^2K/W
[14] New base value according to the Building Decree: Rc=6.3 m^2K/W

- Care
- Hospital: 100 kWh per m^2
- Overnight stay: 80 kWh per m^2
- Care without overnight stay: 90 kWh per m^2
- Medical group practice: 80 kWh per m^2

Several sectors have drawn up roadmaps describing how the sector is working towards the CO_2 reduction targets for 2030 and 2050. The sectoral roadmaps for social real estate include roadmaps for public buildings, such as education, healthcare, and government buildings.

In addition, by making portfolio roadmaps, organizations can make plans for making their real estate more sustainable (RVO, 2022).

To make the social real estate more sustainable, there are support tools available, such as the Guideline for Making Multifunctional Accommodations More Sustainable.

Shared incentive for social real estate

Investments in sustainability and the resulting benefits are often not evenly divided between the parties involved, such as the owner and the tenant. As a result, investment decisions are difficult. As opposed to split incentive (different motives), there are shared incentives (joint motives). There are example projects of organizations that have successfully joined into the collaboration. The examples are about commercial real estate and social real estate such as a theater / community center and a municipal recycling center (RVO, 2022).

Subsidy Scheme for Sustainable Social Real Estate (DUMAVA)

DUMAVA is specifically aimed at encouraging owners of social real estate to take steps in the short term to make their building more sustainable. The subsidy targets the following sectors within public function:

- Decentralized government, such as a building with a public function that is owned by the municipality, province, or water board
- Education, such as buildings of a primary school, secondary school, university, MBO or HBO institution
- Care, such as a hospital, nursing home or nursing home
- Culture, such as a pop stage, art collective or theatre
- National monument that is not a residential house, such as a museum whose building is registered in the national monument register
- Religious institutions, such as a mosque or a church
- Other buildings with a public function, such as a foundation, association, playgroup, community center or community center

This scheme includes financial coverage for energy advice, an energy label and a list of eligible sustainability measures that can be taken (RVO, 2022).

Social Real Estate Unburdening Program

The Social Real Estate Unburdening Program offers support to social property owners through the provinces. Investments are being made in knowledge about sustainability in the sectors. As part of the program, the online tool on financing sustainability has been developed (RVO, 2022).

Signpost financing for sustainability (online tool)

The tool can be used as part of, or separately from, the support from the unburdening program and is intended for owners or users of small social real estate who want to get started with sustainability within the following (sub)sectors:

- Municipal real estate
- Schools (because of the focus on small property owners, specifically primary and secondary education)
- Sports real estate
- Real estate owned or managed by the community center or community center
- Real estate owned or managed by institutions with a cultural ANBI status
- Healthcare real estate

The focus here is on owners who have one or only a few properties or users of real estate with a social function, because it is precisely here that the specialist knowledge about property management and sustainability is often lacking. The tool is focused on trade-offs at the building level and less suitable for considerations at portfolio level. For the municipal real estate portfolio, a calculation model is available from the VNG (RVO).

1.2.3.2 Education – primary and secondary

The sectoral roadmap for primary and secondary education provides a sector analysis, an overview of ambitions and objectives along with the proposed sustainability planning and milestones, and is a collaboration between the Po-Raad, VO-raad and the Association of Dutch Municipalities (VNG). The preconditions and bottlenecks as well as further elaboration points are also discussed in this document.

To help schools get the indoor environment in schools in order, the Dutch government has made subsidies available, making it interesting for school boards to make a future-proof investment in safe and healthy education.

Who are the stakeholders?

The primary and secondary education sectors differ from other sectors in social real estate because of the separate cash flows. Municipalities are responsible for the new construction and expansion of schools (and initial furnishing, first educational package, construction errors, insurance, and property tax). School boards are responsible for maintenance, (minor) adjustments and operation of the buildings. The responsibility for construction and operation lies with the municipality (PO-Raad et al., 2020).

With the school as a property, various liabilities of the building also lie with the school board. Due to the separate cash flows, the school cannot independently invest in the building, while some measures reduce operating costs. This means that making a school building more sustainable is always a joint task for the municipality and school board, with clarity about roles, responsibilities, and the distribution of resources. This must be considered while drafting a business plan which targets sustainability of schools (PO-Raad et al., 2020).

Fresh Schools Guideline (Frisse Scholen)

The Program of Requirements - Fresh Schools helps school boards and municipalities in their role as clients of renovation or new construction. A Fresh School is a school building (primary or secondary education) with a low energy consumption and a healthy indoor environment. In a Fresh School, attention is paid to five themes:

1. Visual comfort
2. Energy efficiency
3. Thermal comfort
4. Air quality
5. Acoustic comfort

There are three quality classes (Class A, B and C) depending on the lifespan in combination with the available budget and ambitions of the school. This program of requirements must be met in at least 95% of the usage time. (Netherlands Enterprise Agency (RVO), 2021).

An online web tool (Fresh Schools ambition guide) is developed in which the project characteristics can be entered to find the basis for the Program of Requirements for a healthy, comfortable and energy-efficient school building.

National sustainability programs for educational buildings

There are several national support programs to help the educational buildings with the sustainability challenge. The program "*Schools on course for 2030*" is a joint broad approach to tackle sustainability challenges. There are a few other programs on specific themes:

- Saving energy: The "*Schools saving energy*" program supports school boards in taking simple measures to save energy in which energy experts (Energy savers) help create insight and determine the first steps and energy saving opportunities (Information Center Ruimte-OK).
- Generating energy: The "*School roof revolution*" program supports solar panels. School roof coaches guide the school boards and regional ambassadors help with quartering at municipal level to visualize local incentive measures for boards (Information Center Ruimte-OK).
- Education and behavior: Encourage students to work in the classroom on climate change, sustainable energy, and the energy transition. Children learn in a playful way about the operation of a solar panel, the energy consumption of a school and how the nature generates energy (Information Center Ruimte-OK).
- Innovation: The "*Natural gas-free schools*" innovation program supports 11 pilot schools in the renovation to a natural gas-free and fresh primary school. The knowledge from the country is collected and shared with other school boards and municipalities (Information Center Ruimte-OK).

1.2.3.3 Education - Secondary and Higher Vocational Education, and university

At MBO, HBO and WO, the institution is often largely responsible for the real estate itself. Sectoral Roadmaps have been drawn up for MBO and HBO in which different scenarios are defined to achieve sustainability ambitions (Jacobs and Kersten, 2020).

1.2.3.4 Healthcare - Cure

Healthcare institutions, governments and companies are working together on sustainability based on the 'Green Deal Sustainable care for a healthy future'. This Green Deal contains agreements for reducing environmental pollution and CO_2 emissions from the healthcare sector. Locally, healthcare institutions and municipalities are also seeking cooperation in the context of the Green Deal sustainable care (RVO, 2022).

Based on the scenario study in the draft sectoral roadmap for cure (2020), the proposed strategies for the health sector are aimed at:

- Implementing the measures from the recognized list of measures (EML).

- Improving the thermal quality of existing buildings at natural moments by up to approximately 80% of the new-built quality.
- Realizing a building quality that exceeds the statutory requirements in new construction.
- Connecting to local heat distribution networks where possible. The initiative for developing however, such systems are outside the healthcare sector.
- Where connecting to a renewable heat distribution network is not possible, transforming the heat generating installations to electric heat pump systems. This still requires innovations to phase out steam production, among other things.
- Installing photo voltage (PV) panels on the roof surface. This can be realized by healthcare institutions themselves or the roof surface is “made available” to third-party initiatives.
- focus on maximizing the use of heat from renewable local and regional heat distribution networks that are developed within the district-oriented approach of the municipalities; or focus on self-generation of heat fed from the public electricity network (heat pumps).
- An increased area of solar panels by 5% per year is also included in both packages.
- That many hospitals also produce their own electricity via combined heat and power (CHP) and that the increase in the gas price envisaged in the Climate Agreement and a possible fall in the electricity price will reduce the profitability of these systems sharply. It is therefore expected that the capacity of these CHP installations will be reduced or that no new natural gas-based installations will be added or replaced.
- A renovation or replacement period of the building envelope of 40 years and 20 years for adjustments and/or replacement of the technical installations.

In total, there are seven packages of measures drawn up in the draft sectoral roadmap for cure (2020), among which the first package is mandatory by law. In addition to the supplementary measures which evolve in each package compared to the previous one, the package of measures for scenario 1 is the mandatory base for all the other packages of measures. The mandatory measures include:

- Implementing the Recognized List of Measures (EML) which mainly influences the energy demand
- When replacing equipment, an autonomous improvement in performance (Eco-design, etc.), reducing electricity consumption by 0.5% per year in the period up to 2050
- The BENG requirements are met for new construction.

In package of measures for scenarios 2 to 4, the following supplement measures (in addition to the measures of package for scenario 1) are included:

- Phasing out CHPs, 7% per year initial percentage of gas use for CHP 10%
- Increase in use of heat from heat distribution 5% per year to a maximum decrease in gas consumption depending on the used package of measures.
- PV installation, increase 5% per year to a maximum of 50% roof surface.
- Transition from gas boilers to heat pumps (decrease in gas consumption depending on the used package of measures); expanded to provide for regional electricity generation (decentralization of electricity generation).
- Installation replacement every 15 years instead of 20 years (package of measures 4.B)

1.2.3.5 Healthcare – Long-term care

It seems that most of the focus of the roadmap is on reducing direct CO_2 emissions, mainly concerning a reduction in natural gas consumption. This strategy is to be achieved by applying efficient heat generation systems. In addition, the aim is to reduce electricity consumption, and to make use of local sustainable energy systems where this is effective.

A few bottlenecks can be addressed from the long-term healthcare (Care) sector that may delay or complicate the implementation of measures to achieve CO_2 emission reductions. These bottlenecks can be distinguished as the following: in the field of government policy and regulations, in the field of organization and financing, or technical bottlenecks such as the use of geothermal energy and other innovative forms of renewable energy generation.

1.3 Energy market rules and tariffs

To find out the causes of the high energy tariffs, it helps to know how the energy tariffs are structured. For example, the following components will be reflected on the energy bill:

- Delivery costs: These are the costs that is paid to the energy supplier for the supply of gas and electricity. These delivery costs are made up of variable and fixed delivery costs. The variable costs are the costs paid for the consumption of gas (m^3) and electricity (kWh). The fixed delivery costs are fixed costs that is paid to the energy supplier, regardless of how much is used.
- Taxes: Various taxes are paid on the supply of gas and electricity, namely energy tax, the Storage Sustainable Energy and Climate Transition (ODE) and VAT.
- Network costs: The network costs are the costs that must be paid to the network operator. This is done by the energy supplier. These costs are region-specific, and everyone is obliged to pay these costs (ENGIE).

To assess the energy price development, it is necessary to take the price at an average annual consumption. The energy price consists of fixed and variable components. Only the variable part depends on the consumption. An average annual consumption is considered because the consumption in the winter is higher than in the summer and it does not make sense to take an average consumption of only January. Consumers also pay the same monthly amount in January as in July, even though gas consumption in January is much higher than in July.

January often experiences the biggest changes in energy prices. The network operators and suppliers adjust their prices, and the government changes the tax rates. The tax rates are fixed for the rest of the year, but the fixed costs for grid management and the supply rates can change during the year.

For the consumer price index, Statistics Netherlands follows the monthly price changes of energy. Statistics Netherlands publishes not only the price index for energy, but also for electricity and gas separately. Figure below shows that the average consumer price of energy fluctuates strongly. Monthly price developments over the past three years show that January prices do not correspond to the average price in a calendar year (CBS, 2021).

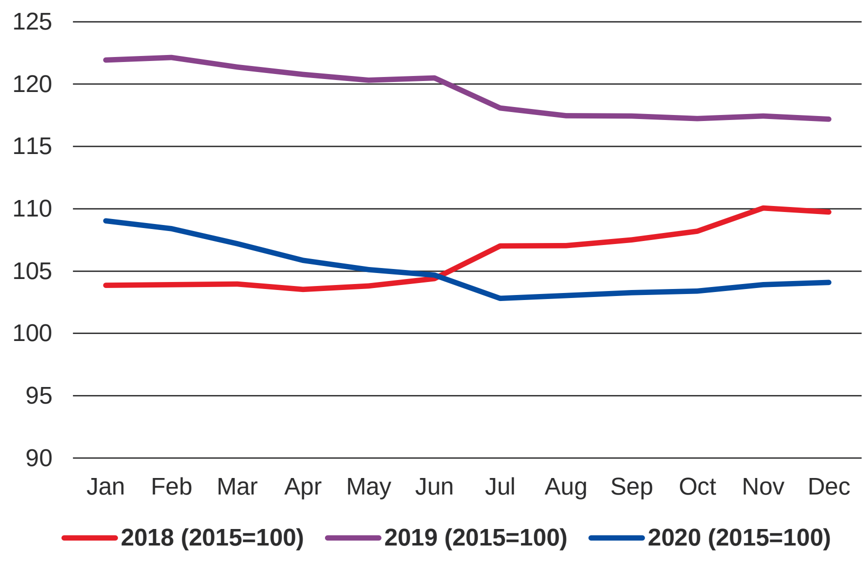

Figure 1-5: Energy price index. Source: CBS

Tax rates do not change after January, but fixed prices for transport and delivery may change over the course of the year, usually with relatively small amounts. In particular, it is the supply price per unit of consumption that can change quite a bit (CBS, 2021).

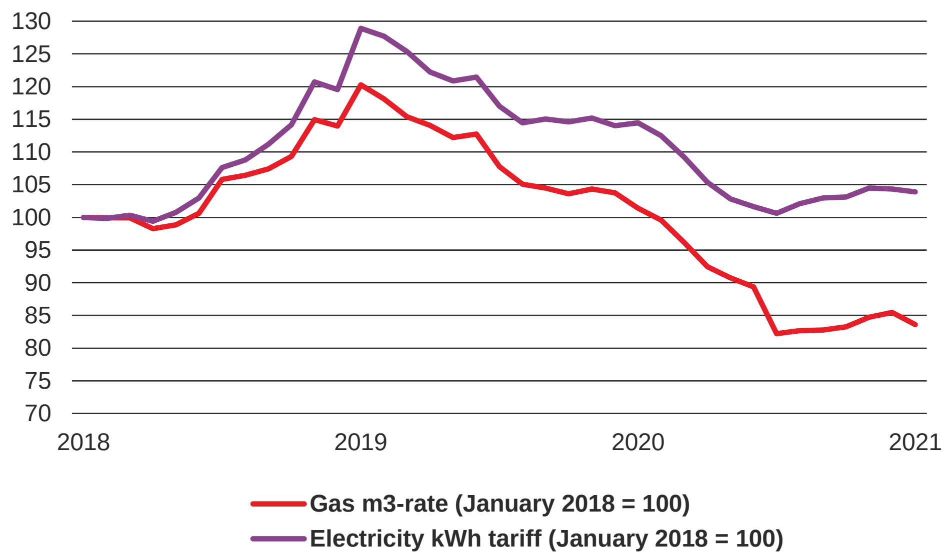

Figure 1-6: Price index delivery rates per consumption unit. Source: CBS

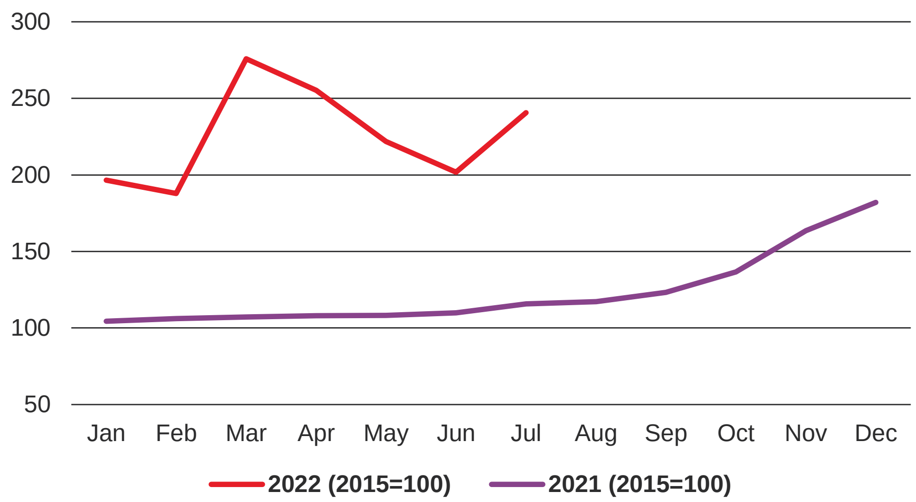

Figure 1-7: Price index electricity, gas, and district heating. Source: CBS

1.3.1 Current energy prices

According to CBS (Central Bureau of Statistics), a household with an average energy consumption pays around 2800 euros for the energy bills in 2022, which is 1321 euros more (86% higher) than the year before. This increase is mainly due to higher supply tariffs for gas and electricity. On the other hand, households pay less energy tax as compensation for the higher supply tariffs, which is on average 417 euros less than the year before.

The cost of energy use depends on whether it is based on a variable energy contract (without a fixed term) or a permanent one. The average price for one year of a fixed contract is less compared to the one of variable contract.

According to research by the ACM[15] (2021), almost 45% of Dutch households still have an energy contract with variable energy tariffs. When the fixed energy contract expires, it is automatically converted into a variable energy contract.

Table 1-1: Average energy costs based on the prices of 20 energy suppliers in The Netherlands. Source: overstappen.nl

	Average electricity price (per kWh)	**Average gas price (per m^3)**
July 2022	€ 0.595	€ 2.589

1.3.2 Energy price forecast

What the energy prices will do in 2023 depends on several factors. The gas reserves and the reserves of the other fossil fuels play an important role in this. Electricity prices are also partly dependent on gas and coal prices. It will take some time before the gas reserves are sufficiently replenished. The prices therefore remain a lot higher than in previous years. This depends on various factors, such as supplies of gas from abroad, winter temperatures, emission rights and much more. These are uncertain factors that cannot be controlled. The EU commission is taking measures to this problem

[15] Autoriteit Consument and Markt. (2021). *Energiemonitor 2021*. https://www.acm.nl/sites/default/files/documents/energiemonitor-2021.pdf

and the Netherlands is NL following. However, the uncertainty remains. Below are the short-term solutions established by the government to overcome the current high prices of energy.

1.3.3 Measures to compensate for high energy prices

To partly compensate for the sharp increase in the energy bills of households and businesses, the government is taking various measures. This includes the following:

1. Lower energy tax on electricity: Why is the tax on electricity being reduced? And why not on natural gas, while the problem is precisely with natural gas? A lot of electricity is generated with natural gas. Because the price of natural gas is rising, the price for electricity is also rising. The tax reduction on electricity mainly compensates households and small businesses, which is why the government has opted for this. The amount of discount depends on the energy consumption.
2. Higher energy tax refund: This is a fixed discount, which does not depend on the energy consumption.
3. Lower VAT on natural gas, electricity, and district heating (Central Government)

1.3.4 Energy tax credit

A tax credit applies to each electricity connection. This is because up to a certain amount, energy use is regarded as a basic need. No energy tax is paid on this basic amount. The government sets the amount of the tax credit each year. The energy supplier deducts the tax credit from the energy bill. Even if the annual energy tax is less than the tax credit, the full amount of the tax credit is still deducted from the bill. The same applies to green energy. If the users move part way through a billing period, they receive a proportion of the tax credit (Central Government).

1.3.5 Reduced energy tax rate

According to the website of Dutch Tax Authorities (Environmental tax rates), a reduced tax rate applies to gas and electricity consumptions below a certain amount. From the 4 mentioned consumption categories in the figures above, gas consumptions below 170.000 m^3 receive the highest reduced rate. Gas consumptions above 1 million m^3 are not eligible for reduced tax rates. The same principle applies to the tax rate reduction for storage of sustainable energy and climate transition (ODE) on natural gas.

The government has decided to lower the energy tax for 2022 to make sure the energy bill for households and SMEs will be less high. The energy tax rate for the 2nd and 3rd level of use brackets will be lowered. At the same time, the tax credit for the electricity bill will be raised.

In 2023, it is expected that the central government will continue to reduce VAT on energy by reducing energy taxes and excise duties. This is mainly aimed at the lower incomes, possibly through the allowances. However, this only concerns the energy taxes and not the final energy prices (Milieu Centraal).

1.3.6 Energy tax exemption or refund

Citizens and companies that generate their own electricity with solar panels and that consume electricity themselves, do not have to pay energy tax on the self-generated electricity. Landlords who install solar panels on a rental property and thereby supply electricity to the tenant also receive an exemption from energy tax. The exemption only applies to the electricity generated by the solar panels (Central Government).

In some cases, businesses can get an energy tax refund. For instance, if they use natural gas and electricity to generate their own electricity. People who share an electricity connection can also qualify for a refund. For instance, if a house is split into two or more flats.

Private individuals with high heating bills cannot be exempted from or get refunds of energy tax. If the heating bill is larger than normal due to old age, handicap, or illness, it is not possible to get a refund of energy tax. But if it is difficult to pay the heating bills, it is possible to qualify for special assistance from the municipality.

VAT and solar panels

Whether solar panels are bought for a company or for a private home, the VAT on solar panels can be reclaimed through a VAT return file (Government information for entrepreneurs). This applies to both private individuals and business owners.

Sustainable energy surcharge

Apart from energy tax, a levy is paid on the supply of energy to stimulate sustainable energy. This is called the sustainable energy surcharge (Opslag Duurzame Energie, ODE). This surcharge is paid per consumed kWh electricity or m^3 gas. The consumer does not have to pay the energy tax surcharge if they use:

- electricity generated by the consumer from renewable sources
- electricity generated by the consumer with a backup installation in case of disruptions in the distribution network
- landfill gas, sewage gas or biogas produced by the consumer
- electricity generated by the consumer with a cogeneration plant

1.3.7 Subsidies

Between the residential and non-residential buildings, some subsidies are in common. For example:

Investment Subsidy for Sustainable Energy (ISDE)

Business-owners who want to produce their own sustainable energy in the business premises, may be eligible for a sustainable energy investment subsidy. This subsidy will partly compensate for the initial investment costs of the device. The actual compensation depends on which device is purchased and its energy performance. Business-owners can be from the following list:

- self-employed professionals
- housing associations and homeowners' associations (VvE)
- partnerships, foundations, and associations
- municipalities, provinces, and public entities as market party or as owner or tenant of (im)movable assets
- private commercial lessors of housing or business spaces (these do not need a Dutch Business Register (KVK) number)
- commercial operators from abroad that want to install one or more devices in the Netherlands

Different types of sustainable energy production can be used on the premises, such as:

- connecting to a heat grid
- small-scale wind turbine
- heat pump
- solar boiler

- solar panels

For suppliers, manufacturers, or (building) installation companies, it can be a business strategy to have their products (such as heat pumps, solar boilers, low-E glass, or insulation material) listed with RVO on the ISDE devices and insulation measures list. If the product is listed, customers know they may be eligible for the ISDE subsidy (RVO).

1.3.7.1 Subsidies for non-residential

For this category, which includes utility buildings such as offices or social real estate, the following subsidies are available:

Energy Investment Deduction (EIA)

Companies in the Netherlands who want to make energy investments in the built environment, may be eligible for the Energy Investment Deduction (EIA). This scheme offers a tax deduction if the company invests in assets that are described on the Energy List. The average tax reduction is approximately 11%. Even if the investment is not specifically described in the Energy List, the project may still be eligible, under a generic code (RVO).

Environmental Investment Deduction (MIA)

Entrepreneurs in the Netherlands who invest in environmentally friendly business assets, may be eligible for the environmental investment allowance (milieu-investeringsaftrek, MIA). With the MIA, entrepreneurs benefit from an investment deduction that can amount to 45% of the investment amount. That deduction is in addition to the usual investment deduction (RVO).

Random Depreciation of Environmental Investments (VAMIL)

Entrepreneurs in the Netherlands who want to invest in environmentally friendly assets and techniques may be able to use the Random depreciation of environmental investments scheme (Willekeurige afschrijving voor milieu-investeringen, VAMIL). With the VAMIL, 75% of the investment costs can be written off for a random year, resulting in liquidity and interest advantage. The VAMIL scheme can be applied in addition to MIA (RVO).

With the MIA/VAMIL, the net tax benefits can amount to more than 14% of the investment amount (RVO).

Geothermal energy guarantee scheme

The resulting profits from investing in geothermal energy can be lower than expected. Therefore, the Geothermal energy guarantee scheme has been established to insure against financial risk. Business-owners who want to make their business more sustainable by investing in a geothermal energy project can apply for the scheme if they meet certain criteria. In that case, they must pay the premium of the Geothermal energy guarantee scheme (RNES Aardwarmte) before they start, insuring them against the financial risk of a potential low energy yield (RVO).

Opportunities for West (Kansen voor West)

SME business-owners in the western part of the Netherlands can apply for a subsidy for innovative projects from Opportunities for West. To apply for this subsidy, the project idea must fit one of the priorities of Opportunities for West III:

- Innovation: to encourage an innovative and smart economic transition
- Energy efficiency: to increase the use of efficient measures to reduce carbon emissions
- Renewable energy: to encourage the use of renewable energy sources

- Smart energy systems: to develop smart energy system, grids, and storage
- Circular economy: to encourage the transition to a circular economy
- Durable urban development: to support effective and inclusive employment, education, skills, social inclusion, and equal access to healthcare and develop the role of culture and sustainable tourism in urban areas

In the Netherlands, micro-businesses, small and medium-sized businesses all fall under the title of "*Small and Medium-sized Enterprises*" or in short, SME. When determining if a business is eligible for an SME grant or subsidy scheme, the Netherlands Enterprise Agency uses the EU criteria. However, the Netherlands Chamber of Commerce uses different criteria to determine in how much detail a company must deposit their annual financial statements (RVO).

Subsidy scheme Improving Sustainability of SMEs (SVM)

SME-owners who want to improve the sustainability of their company can apply for this subsidy. They will be provided with advice from an expert on how to reduce the company's emissions and carbon footprint. The SVM also subsidizes indirect costs to carry out one or more of the recommendations (RVO). The advisor's recommendations can include (but not limited to):

- Adding insulation or LED lighting
- Applying sustainable technologies, such as solar panels or heat pumps
- Taking other energy-saving measures, such as replacing company cars, kitchen, or office appliances for more sustainable alternatives

Sustainable energy transition subsidy scheme (SDE++)

Companies in the Netherlands that produce renewable energy or use techniques that reduce CO_2, can apply for this subsidy (*Stimulering Duurzame Energietransitie, SDE++*). This is a subsidy for a period of 12 or 15 years, depending on the technology used (RVO). The following energy techniques are eligible for SDE++:

- renewable electricity
- renewable heat and CHP
- renewable gas
- low-carbon heat
- low-carbon production

1.3.7.2 Subsidies for residential

Subsidy scheme for Cooperative Energy Generation (SCE)

Energy cooperatives and homeowners' associations (VvE) who want to generate renewable electricity from solar energy (PV), wind energy, or hydropower, may be eligible for the Subsidy scheme for Cooperative Energy Generation (*Subsidieregeling coöperatieve energieopwekking, SCE*). This scheme replaces the reduced rate tax provision (*postcoderoorsregeling*). The scheme applies to connections for low-volume users as well as for bulk users. To be eligible for this scheme, the energy generation facility must be owned by the party who wants to apply for the subsidy. For this scheme, financial lease is also considered ownership (RVO).

There are different subsidies and financial schemes offered by the government that stimulate taking energy-saving and sustainable measure such as:

- connecting existing rental houses to an external heat network

- purchase of heat pumps, solar panels, biomass boilers, solar water heaters, pellet stoves and small wood-fired boilers (subsidy applicable to households and small commercials) (MURE Database).
- implementing small energy-saving measures e.g., for improving heating installations/insulation (control, radiator folium, insulation, etc.)
- producing renewable energy or utilizing techniques that reduce CO_2 (applicable to renewable electricity, renewable heat and CHP, renewable gas, low-carbon heat, and low-carbon production)
- Extending mortgage options (increased sum investment) for energy-saving measures (MURE Database).
- Reduction of landlord charges for housing associations (RVV) (aimed at housing associations in the social housing sector) (MURE Database).

1.4 Conclusions

As discussed in section A.1.1, Dutch households used to not be interested in energy related home investments compared to households in other countries. However, this has changed and there is a growing interest among Dutch households. Therefore, the business plan should be composed in such a way that makes this transition more appealing and based on the mindset of the target people. This could in particular include options that directly reduce the investment costs for the users, options that return back something tangible to the users, reducing the payback time of the investment costs, etc.

Possible business plan for the Dutch market could be structured like a matrix, based on each target group and their specific needs/behaviors:

1. Residential sector:
   a) Per ownership: change of central heating boiler with multi-source heat pump in combination with a financial coverage proposal that makes it affordable. This can be used for all ownership types.
      - owner-occupied
      - Private rental
      - Housing association

   b) Per income group:
      - Low-income and middle-income → changing the central heating boiler with the multi-source heat pump, in combination with an investment coverage proposal, plus offering a recurring maintenance plan or allocating subsidies to carry out the necessary maintenance. Maybe also include additional bonus points for this income-range to encourage them to take the steps. The application of this plan could be at neighborhood scale, to reduce the overall costs and time for the responsible company.
        Another option could be to offer package deals to this category. For example, combine the installation of the multi-source heat pump with installation of PVTs as the “bonus”, or other combinations that might be appealing to low-income families.
      - High-income: Plans targeting high-income households might be more individually/per household applied. If a whole neighborhood is identified as high-income, then maybe the application could be at neighborhood scale.

   c) Per age group:
      - Young households
      - Elderly households

Plans targeting elderly households should consist of shorter payback time or receiving a benefit in a tangible form. For these households, another possible solution could be that parties who offer the IES solution, also provide the maintenance so that the users do not have to be concerned with that and its costs.

For young households, the payback time could be longer.

2. Office sector:
   a) Owner-occupied
   b) leased
3. Public sector

Regarding the policies and regulations, most policies in the residential sector do not provide an IES solution. In addition, there is not a clear overview of the limitations of these incentives such as the use of F-gasses in heat pumps or limiting the material impact (LCA's).

Similar to the residential sector, in both office sector and public sector, a lack of an overview of the limitations of the policies is evident. Also, there is a lack of policies that provide IES solutions and technologies.

In the education sector, most of the focus is on transition to a gas-free building as well as generating energy or improvement of insulation while for the healthcare sector, the transition mostly aims at reducing the CO_2 emissions, connecting to a heat distribution network, energy generation, reduction in natural gas consumption, and transition from gas boilers to heat pumps. There are packages of measures for the healthcare sector in the sectoral roadmap which focus on various targets, but still require individual and apart measures to be taken, rather than one holistic IES approach that could achieve all the objectives together.

2 Appendix B: Germany

2.1 Cultural, economic, and social aspects

Although Germany's post-war industrial and economic recovery is, and has been, built on the back of fossil fuels, strong political support for the reduction of carbon dioxide emissions has grown in recent years. Established in the 1980's, the Grüne/Greens party has seen a surge in support for pro-environmental policies favoring the phase-out of fossil energy in the 2021 election. Further, the recent conflict in Ukraine has bolstered public support for energy security, including pledges for increased renewable exploitation[16] and the continued (purportedly temporary) use of oil and coal[17].

Decreasing affordability and real wage growth[18], as well as increasing energy prices (up to +300% domestic electricity and gas price relative to 2021) and inflation (+10.9% relative to 2021)[19], has put pressure on German citizens, reducing their capacity for capital investment. This financial pressure was previously acknowledged in Berlin through the 2015 *Mietenvolksentscheid* ("Renters Referendum"), which sought to apply a rent ceiling and expropriate assets held by large housing companies in Berlin. While falling short of expropriation, the movement led to the *Berliner Wohnungsversorgungsgesetz* (Berlin Housing Supply Act) which legislated more state intervention and socialized housing. Therefore, most of the German public are expected to respond to economic motives - unwilling to sacrifice comfort and standards of living in the pursuit of sustainability, rather their bottom line.

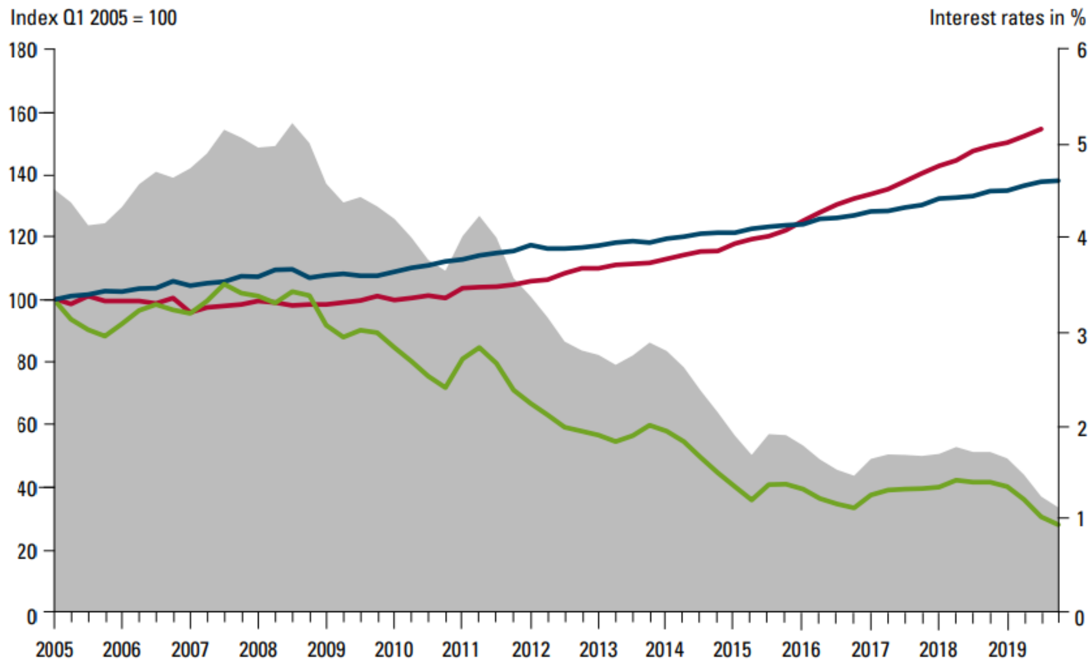

Figure 2-1: Mortgage interest rates (grey), house prices (red), income (blue) and affordability (green) ©BBSR Bonn 2020 [18]

16 SPD (2021). More Progress Dare: Coalition Agreegment 2021-2025
17 Bundesregierung (2022). Less gas consumption in an emergency
18 Federal Institute for Research on Building, Urban Affairs and Spatial Development (2021). Housing and property markets in Germany 2020.
19 Germany Central Bank (2022). Monthly Report – October 2022

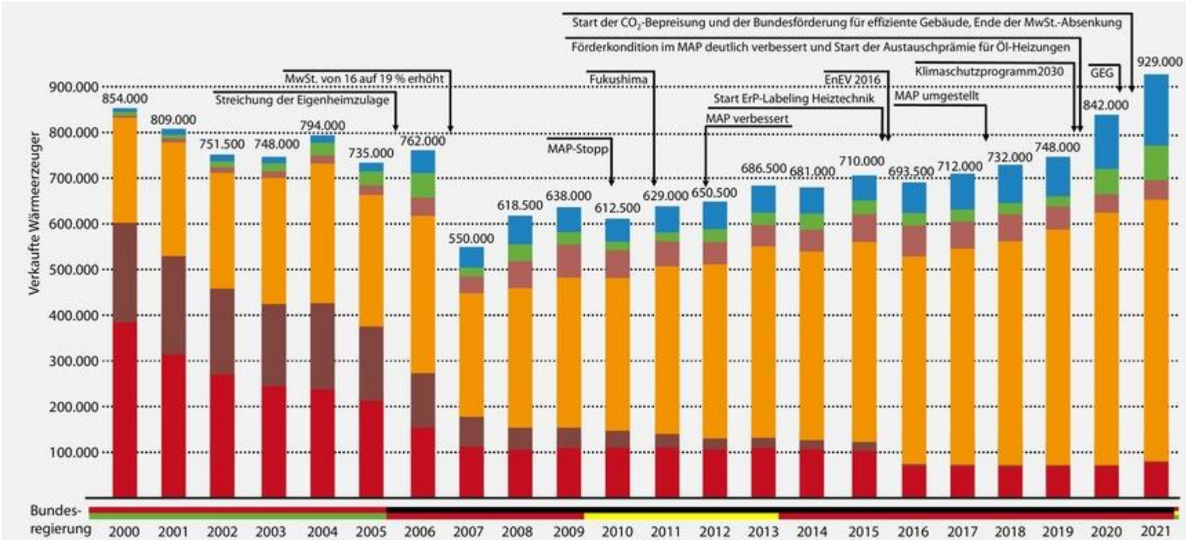

Figure 2-2: Heating systems sales
heat pumps (blue), biomass boiler (green), oil vessel (brown), condensing gas boiler (orange), low-temperature oil boiler (dark brown) and low-temperature gas boiler (red)
© Bundesverband der Deutschen Heizungsindustrie (BDH) 2022 [18]

The Building Energy Act (GEG) has pushed (through partial ban on fuel oil, solid fossil fuel and gas boilers) and pulled (through subsidies via the Federal Support for Efficient Buildings (BEG)) the space heating market – causing significant growth in the heating industry. Sales are up 25 percent from 2019, with condensing gas boilers making up the significant market share, followed by a growing demand for heat pumps and biomass boilers. The significantly lower gas price (prior to 2022), lower initial investment and ability to easily convert from other high-temperature heat sources are expected to be the core reasons for the prevalence of condensing gas boilers in sales statistics. However, the market landscape is expected to dramatically change with higher gas prices and new leadership.

After 2022, the public bank Kreditanstalt für Wiederaufbau (KfW) is finished its role in subsidisation provision, with responsibility shifting to Federal Office for Economic Affairs and Export Control (BAFA). While the Federation of German Heating Industry (BDH) has promoted steady and unchanged subsidies[20], the amendments to the Building Energy Act (GEG 2025) set out stricter guidelines for subsidies – raising the standard of new builds to *Efficiency House 55* from 2022-2024 and *Efficiency House 40* from 2025 onwards. Further, plans for the introduction of 65% renewable heating for new heating systems and solar roof obligations are expected to roll out in 2024. This is only possible with heat pumps, biomass heating systems and those in a hybrid heating system, however, heat supplied by CHPs are considered ‘renewable energy’ sources under the current GEG 2020. Seemingly, the era of gas heating is already coming to an end; oil heating has not played a role for years.

[20] Bundesverband der Deutschen Heizungsindustrie (2022). *Marktentwicklung Wärmeerzeuger Deutschland 2000–2021*

2.1.1 Residential

According to the Federal Office for Building and Regional Planning, renters constitute 49% of households in Germany (but can be as high as 85% in cities like Berlin[21]) – one of the highest percentages in Europe. Two-thirds of all homes for rent are owned by private individuals with modest property portfolio sizes, with approximately half of corporate landlords (15% of total rentals) having a portfolio of between 20 and 1,000 properties[18]. The financial crisis of 2008 facilitated the shift of ownership towards a small number of very large listed real estate companies and any future economic recession is expected to show similar trends[22]. Therefore, the proportion of renters is expected to remain stable or increase in the short to medium term.

The high proportion of renters in the residential market is associated with both incentives and barriers for renovation due to the unequal distribution of return - known as "split incentives". The process of modernization incentivizes fast, cosmetic renovations aimed toward securing higher rental incomes for owners. The landlord minimizes expenses for the maximum return – meeting minimum regulations while investing in finishes and appearance. The ability of landlords to pass on operational costs disincentivizes renovations targeted toward energy performance, such as those associated with systems and envelope improvements. Conversely, tenants are incentivized (by operational expenses) to improve the energetic performance of their home, but often don't feature a time horizon stable enough for investment payback, are disempowered by the overhead or legality of landlord negotiation, or lack the capital required for such ventures[23]. The outcome – only every third renovation undertaken in Germany results in energy saving measures and most measures do not meet the optimum renovation depth[21].

Standards enforcement policies, revisions to laws aimed at empowering tenant-landlord cooperation, individual metering, financial and fiscal incentives, and government loans are solutions to the *split incentives* of the residential housing market[23]. Often, energy efficiency standards and financial incentives for landlords have been employed – showing great effect for new buildings but limited success for existing buildings (i.e., renovations). According to a study by Weber and Wolff[24]:

"*Alongside existing government incentive programs, the German tenancy law allows landlords to add a maximum of 11% of the energy-related modernization costs onto the annual rent… Despite a reduction in energy consumption of 70%, more than half of the households faced increased costs due to higher rents after retrofit*."

Due to the lack of affordable housing currently observed in most German cities, tenants are more willing to accept high energy costs. Initiatives supporting tenant-landlord or multi-owner cooperation may be a more effective strategy to drive renovations targeting energy performance. The EU Commission suggests one such measure as revisions to rent acts which "lay out [a] legal framework and specific conditions for the redistribution of investment cost and energy cost savings of an energy efficiency upgrade between the landlord and the tenant or between multiple owners"[23].

[21] BPIE (2020). The residential building renovation market in Germany, Italy, Lithuania and Spain
[22] Wijburg and Aalbers (2017). The alternative financialization of the German housing market. Housing Studies, 32(7)
[23] Institute for Energy and Transport (2014). Overcoming the split incentive barrier in the building sector
[24] Weber and Wolff (2018). Energy efficiency retrofits in the residential sector – analysing tenants' cost burden in a German field study. Energy Policy 122, 680-688

2.1.2 Offices

The problem of split incentives is not as strong in the commercial building sector as in the residential sector for several reasons:

- **Corporate Ownership**: Unlike the residential market, both landlords and tenants of commercial buildings tend to be corporate and concerned with public image - aware of the growing social pressure to decarbonize.
- **Reduced Demand**: The depression of commercial property demand due to worsening economic circumstances and growing digitalization of work/commerce increases the tendency of landlords to yield tenant needs (i.e., low operational costs, low carbon/energy intensity)
- **Government Regulation**: The development and eventual enforcement of the EU Taxonomy will put regulatory and financial pressure on non-performant buildings.
- **Larger Portfolios / Resources**: Owners of commercial properties are expected to feature larger portfolio sizes with economies of scale – streamlining asset screening, decarbonization/efficiency planning and access to financial incentives which would otherwise feature high overhead costs.

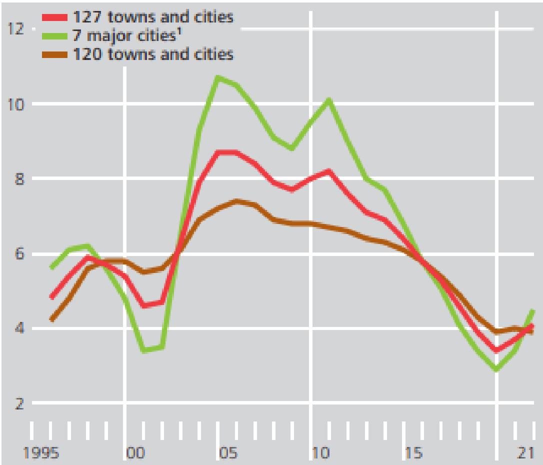

Figure 2-3: Vacancy rate (%) for offices in Germany published
© Deutsche Bundesbank, 2022[25]

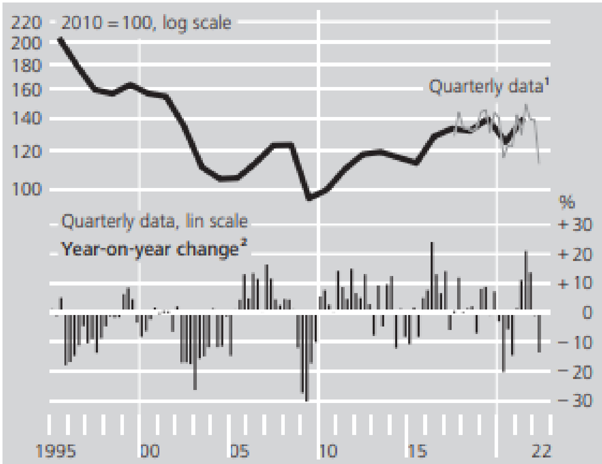

Figure 2-4: Annual new orders for commercial building construction in the main construction industry in Germany (constant prices)
© Deutsche Bundesbank, 2022[25]

While the conditions look suitable for energy and decarbonization potentials, some threats and barriers remain. Threats include the poor real (i.e., inflation adjusted) commercial building indicators (signaling a declining market), which could restrict finances for measures toward the energy transition. Following the fallout of the 2008 financial crisis, COVID 19 pandemic and European energy crisis, the commercial building market faces a concerning lack of demand, with vacancy rates up and new orders for commercial buildings in rapid decline (Figure 2-4)[18 25]. Alternatively, barriers such as the remaining lifespan of existing building components (particularly gas boilers) and compensation for tenant interruption (business downtime) are major economic considerations for landlords. However, given energy prices and tenant market power, the short-term outlook for energy efficiency targeted renovations in the commercial building sector seems positive.

[25] Deutsche Bundesbank (2022). System of indicators for the German commercial property market

2.1.3 Public

Public buildings, such as state offices, schools, sports facilities, and laboratories, are important institutions in the public eye, representing the attitude and values of the various levels of government. The number of buildings differs depending on governmental level, with the construction volume of the *Bundesland*, or “state”, *Landkreis*, or “region”, and *Kommune*, “municipality”, owned public buildings many times greater than federal. In 2020, approximately 25 billion euros (or 55 %) of the construction budget of state level of government were attributable to the municipalities - approximately 10 times the spending at a federal level [26]. Like the commercial sector, the renovation of existing public buildings has a far greater impact when compared to new builds, with the renovation rate requiring acceleration. Therefore, the ambitions and standards held by regional and municipal governments have much greater impact than those at a federal level, particularly when concerning the renovation of existing buildings.

Unlike the private commercial and residential sectors, the public sector does not show strong sensitivity to market forces. Instead, specific laws and mandates must drive the energy and carbon performance of the publicly owned building assets:

Building Energy Act (GEG)

For this reason, the Building Energy Act (GEG) sets the public sector as a role model for society and the private sector – having stricter energy efficiency and renewable targets for new constructions and renovations.

Sustainable Building Assessment System for Federal Buildings (BNB)

On federal level, large new build and refurbishment projects of state property and buildings are obliged to undertake a certification of the Sustainable Building Assessment System for Federal Buildings (BNB), which was developed for public building projects in Germany in 2015.

Motions to improve sustainability in the construction and real estate industry

Further, in 2020 the federal government have also discussed the "Initiate a turnaround in the construction – for a resource-saving construction and real estate industry"[27] and the "Innovative, future-proof and sustainable – role model confederation - promoting the buildings of tomorrow today"[28] motions. The first motion aims to facilitate the use of recycled building materials, more resource conservation in the construction and real estate industry, a legally prescribed resource certificate for buildings, a mandatory life cycle assessment (LCA) of buildings and mandatory use of 100 percent renewable heat in new buildings by 2025. The second motion aims to establish guidelines for the sustainable, economical, innovative construction (including the procurement and use of building materials), with federal buildings acting as a role model.

While these measures are great at a federal level, municipal and state governance is only *advised* to introduce an energy and climate protection management system. Due to their much large scale of building stock compared with the federal government, the lack of unified sustainability goals at a state and municipal level may limited the impact of programs such as the BNB. Without market forces guiding the public building sector, no ambitions or actionable targets means no change.

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[26] Deutscher Städtetag Berlin und Köln (2021). Nachhaltiges und suffizientes Bauen in den Städten
[27] Deutscher Bundestag (2020). Bauwende einleiten – Für eine ressourcenschonende Bau- und Immobilienwirtschaft
[28] Deutscher Bundestag (2020). Innovativ, zukunftssicher und nachhaltig – Vorbild Bund – Das Bauen von Morgen heute fördern

2.2 Building codes and regulations

2.2.1 Federal Climate Protection Act (KSG 2021)

In 2021, an amendment to the Bundes-Kilmaschutzgesetz (KSG), or “Federal Climate Protection Act”, of 2018 codified the goals for the country to become climate neutral by 2045 in a legally binding obligation – where the state is obliged to actively take precautions to ensure no disproportionate restrictions of fundamental liberties for the youth of today[29]. Germany pledged to reduce greenhouse gas (GHG) emissions by 65% in 2030, and 88% in 2040 (relative to 1990 levels) - achieving neutrality by 2045 and negative emissions by 2050. The amendment stipulates goals for various sectors, with buildings’ targets currently on-track However, the trend of the past decade does not bode well, with the Umwelt Bundesamt, or “Federal Office of Environment”, stating that without massive and rapid additional efforts, further goals will not be achieved.

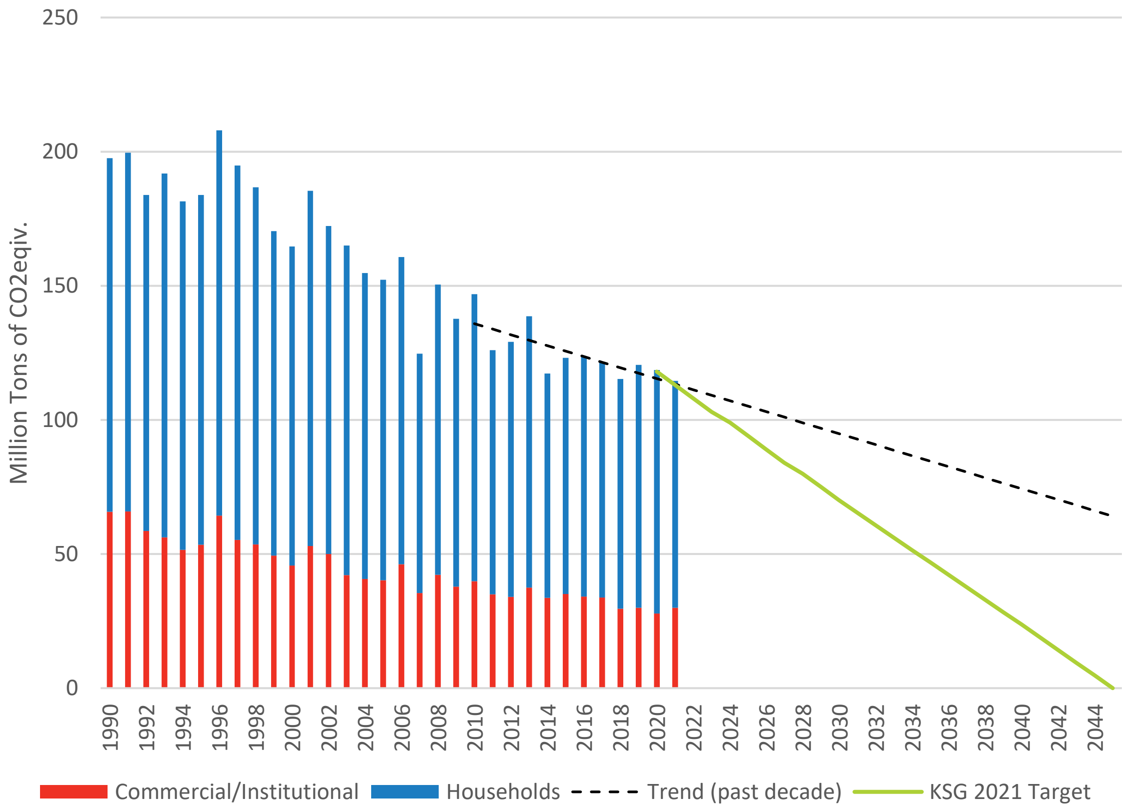

Figure 2-5: Carbon dioxide equivalent emissions of the building sector[30]
**KSG 2021 Target line linearly interpolated*

[29] Die Bundesregierung (2021). *Generationenvertrag für das Klima*. Klimaschutzgesetz: Klimaneutralität bis 2045 | Bundesregierung

[30] German Federal Office for Environment (2022). *Greenhouse gas emissions*. Indicator: Greenhouse gas emissions | Umweltbundesamt

2.2.2 Federal Climate Protection Program for 2030 (KSP 2019)

The Kilmaschultzprogramm, or "Climate Protection Program", of 2019 introduced the pricing of CO2 equivalent emissions for transport and heating – 25 euros per ton from January 2021 to an expected 55 euros in 2025[31]. The government will pay back revenues from carbon pricing through lower taxes and levies on electricity among other social welfare programs. The building sector is expected to benefit via:

- **Tax relief for energy-efficient renovation**
  From January 2020 until December 2029, energy-efficient renovation measures, such as replacing heating systems, fitting new windows, and installation of insulation, payable tax can be reduced by 20 percent of the renovation costs – spread over three years (only applies to owner-occupied residential property)
- **Higher funding for energy-efficient building and renovation (obsolete)**
  From January 2020 until December 2020, Kreditanstalt für Wiederaufbau (KfW) now grants a maximum of €120,000 in low-interest loans with a repayment grant of up to 40 percent for buying, renovating, or building energy-efficient houses. For individual renovation measures, funding of up to 20 percent of the cost is also available.
- **Replacement of oil heating (obsolete)**
  From January 2020 until December 2020, grants of up to 45 percent are available to property owners who replace oil heating systems with a more energy-efficient heating system under the Marktanreizprogramm (MAP), or "Market Incentive Program" implemented for the Federal Office for Economic Affairs and Export Control (BAFA).
- **Ban on oil heating**
  From 2026 onwards, installations of pure oil heating system in buildings will no longer be permitting if a more climate-friendly heating system is possible (this order is included in the Gebäudeenergiegesetz (GEG), or Buildings Energy Act).

2.2.3 Federal Climate Protection Action Program for 2022 (KSSP 2022)

Via an additional funding package of 8 billion Euros, the Kilmaschutz-Sofortprogramm, or "Climate Protection Action Program", of 2022 aim to accelerate the previous Climate Protection Program of 2019. The building sector is earmarked to the lion's share of this package - 5.5 billion euros by 2025[32] – for the refurbishment of residential buildings targeting energy-efficiency, climate-friendly new construction projects and general renovation of social housing. Simultaneously, the minimum energy standards for new building are to be raised. Tangentially related, funds for the expansion of heating networks will be increased, along with the expansion of the Nationale Wasserstoffstrategie, or National Hydrogen Strategy, to include the development of offshore electrolysis plants.

[31] German Federal Government (2018). *Climate Action Programme 2030*. Climate Action (bundesregierung.de)
[32] German Federal Government (2022). *Kilmaschutz-Sofortprogramm.* Bundesfinanzministerium - Sofortprogramm für mehr Klimaschutz

2.2.4 Further energy-saving measures

In August 2022, the German government adopted further energy-saving measures, which were also approved by the Federal Council[33]. The aim is to further promote independence from Russian gas supplies. In addition, the energy-saving measures also serve as a contribution to implementing the savings targets of the European Union, whose states have undertaken to reduce their gas consumption by at least 15 percent from August 2022. On the one hand, gas is to be saved, and on the other, measures are to be taken to reduce electricity consumption, as this will help to reduce the amount of electricity generated with gas.

Among other things, specific short[34]- and medium[35]-term measures have been taken for building occupants, which will apply to the 2022-to-2023 and 2023-to-2024 winters. Tenants are allowed to voluntarily lower the room temperatures in their apartments even if a higher minimum temperature has been contractually agreed. Usually, the contracted minimum temperature is higher than would be required to protect the apartment from damage (mould formation). In addition, consumers will be informed more quickly about possible gas price increases.

Building owners will be required to optimize their buildings' heating systems. This includes an inspection of the heating system (especially gas) for basic setting deficiencies and for the need for further measures. Owners of larger buildings are required to have the installed heating system hydraulically balanced. The replacement of inefficient, uncontrolled heating pumps in buildings with central heat supply is to become mandatory. Heating private pools with gas is to be prohibited in the future.

In workplaces, the minimum room temperature required is lowered by one degree[36]. The respective company may continue to regulate the room temperature independently. In addition, rooms where people do not regularly spend time should no longer be heated. These include corridors, large halls, foyers and technical rooms. This is to be regulated in ordinances.

Large industrial companies with high energy consumption are to implement energy-saving measures that pay off economically within two years. Companies are no longer allowed to use luminous or light-emitting advertising installations. Furthermore, building owners are obliged to optimize the heating systems of their buildings.

In addition to measures for residential and private non-residential buildings, the German government specifically adopted measures for public workspaces and architectural monuments in August 2022. In public workplaces, the maximum temperature may not exceed 19 degrees. The common areas where people are not permanently present (e.g., corridors, large halls, foyers or technical rooms) may not be heated at all. This is to be regulated in ordinances. The hot water should be switched off completely or the temperature reduced to the minimum hygienic level where it is only used for washing hands. As an additional measure, the lighting of architectural monuments has been prohibited unless it is necessary to maintain traffic safety or to prevent other hazards.

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[33] Die Bundesregierung (2022). *Weitere Energiesparmaßnahmen beschlossen.* Kabinett: Weitere Energiesparmaßnahmen beschlossen | Bundesregierung

[34] Bundesministerium für Wirtschaft und Klimaschutz (2022). *Verordnung zur Sicherung der Energieversorgung über kurzfristig wirksame Maßnahmen.* ensikumav.pdf (bmwk.de)

[35] Bundesministerium für Wirtschaft und Klimaschutz (2022). *Verordnung zur Sicherung der Energieversorgung über mittelfristig wirksame Maßnahmen.* ensikumav.pdf (bmwk.de)

[36] Die Bundesregierung (2022). *Weitere Energiesparmaßnahmen beschlossen.* Kabinett: Weitere Energiesparmaßnahmen beschlossen | Bundesregierung

2.2.5 Building Energy Act (GEG 2025)

The objective Gebäudeenergiegesetz (GEG), or "Building Energy Act", is to unify energy conservation legislation for buildings to form a simpler regulatory framework for lowest energy building standards. The new building energy law (valid since the 1st of November 2020) combines three former laws:

- Energieeinsparungsgesetz (EnEG), or "Energy Conservation Act"
- Energieeinsparverordnung (EnEV), or "German Energy Saving Ordinance"
- Erneuerbare-Energien-Wärmegesetz (EEWärmeG), or "Renewable Energies Heat Act"

On the 1st of January 2023, there will be a new legislation in preparation for the GEG 2025, which will enforce stricter requirements for existing buildings – replacing the previous GEG 2020.

The GEG applies to heated and cooled buildings as well as the systems and equipment for heating, cooling, ventilation, lighting and domestic hot water supply. This excludes:

1. Production processes (i.e., manufacturing, computers, industrial process etc...)
2. Underground structures
3. Greenhouses
4. Air domes and tents
5. Temporary buildings (<2years use)
6. Religious buildings
7. Residential buildings used less than four months per year or whose expected energy consumption is 25 percent of the reference annual energy consumption.
8. Other craft, agricultural, commercial, industrial or public utility buildings which feature a heating set point <12 degree Celsius or heated < four months or cooled < two months per year.

The GEG 2025 aims to address energy and emissions performance through the following[37]:

1. New Buildings
    a. Modelled **annual primary energy demand** must not exceed 0.55 times the value of a reference building of the same geometry, floor area and orientation (from the 1st of January 2023)[38].
    b. The **specific heat transfer coefficient** of the building envelope will not exceed 0.7 times the reference building (from the 1st of January 2023).
    c. **Use of renewable energies** (§ 10 Abs. 2 Nr. 3 GEG):
        i. 15% of heating/cooling demand met by solar thermal or renewable electricity.
        ii. 50% of heating/cooling is met be environmental or waste thermal sources directly or in combination with a heat pump, solid biomass, liquid or gaseous biomass in combination with a combined heat and power generator (CHP).
        iii. 50% of heating/cooling is met through district services where a significant proportion originates from renewable energies, >50% is from waste heat, >50% is from CHP plants, or >50% is through a combination of renewables, waste heat and CHP plants (§ 34 - 45 GEG 2023)
2. Existing Buildings

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[37] German Federal Government (2020) *Gebäudeenergiegesetzes*. GEG.pdf (gesetze-im-internet.de)
[38] German Federal Government (2022) *Änderung des Gebäudeenergiegesetzes*. Microsoft Word - 220429 Ressortabstimmung Referentenentwurf-EH_55.docx (energie-m.de)

a. **Envelope replacements cannot impair energy performance**:
    i. Modelled performance of replaced exterior components cannot exceed by more than 40% the primary energy demand of the reference building (if replacements are >10% of total envelope area)
    ii. Cannot exceed the max. reference building specific heat transfer coefficients by more than 40% for residential and 75% for non-residential.
b. Buildings heated to 19 degrees Celsius for more than 4 months per year must have **roof insulation which doesn't exceed 0.24 W/m²K** in general applications.
c. Heating, cooling, ventilation and domestic hot water **equipment replacements cannot impair energy performance.**
d. **Operating ban for oil and gas boilers** (4 to 400kW) installed >30 years ago.
e. **Boilers fired with fuel oil or solid fossil fuel are banned** from 1st January 2026 unless:
    i. the existing building uses a significant amount renewable energy, or
    ii. the existing building cannot be connected to district gas or heating network.
f. **Renovations to central heating systems must be equipped with automated set-back and off** modes of operation.
g. **Limitation of newly installed air conditioning** (> 12 kW) **and ventilation** (>4000m^3/h) in accordance with DIN EN 16789-3:2017-11
h. **Renewed ventilation systems must feature heat recovery** unless:
    i. the recovered heat cannot be used, or
    ii. the supply and exhaust air systems are spatially separated.
i. **Thermal insulation of newly installed/replaced pipelines and fittings**

Significant renovations must now be accompanied by a free choice and no-charge energy consultation. Real estate sellers and owners are required to submit an energy performance certificate (internationally comparable with an EPC rating). Toward the end of 2025, it will be possible to consider several buildings or individual quarters in relation to each other. An innovation clause that enables the testing of innovative power-to-x technologies or the use of synthetic energies will be part of the law

As of 2024, DIN V 18599 "Energy performance evaluation of buildings" will become the sole accounting rule for demonstrating the energy quality of buildings and will replace DIN V 4108 Part 6 and DIN V 4701 Part 10. There are currently two different calculation methods to assess the impact:

1. Calculate the **primary energy** that new construction may require. The decisive factor here is the energy source used, which is multiplied by a specific "primary energy factor" (part of the energy supply must be covered by renewable energies).
2. Calculate the amount of allowable **greenhouse gases** (CO_2) that new construction may produce. For this method, an application must be submitted to the relevant authority, along with a follow-up report post-construction. Consumption of energy sources are multiplied by their respective emissions factors (which differ from the primary energy method). Final energy may not exceed a certain value when calculating greenhouse gases, and the supply of the building by renewable energies is not prescribed.

2.2.6 Federal Support for Efficient Buildings (BEG)

The Federal Support for Efficient Buildings - *Bundesförderung für effiziente Gebäude* (BEG for short) - combines previous support programs for promoting energy efficiency and renewable energies in the building sector and supports, among other things, the use of new heating systems, the optimization of existing heating systems, measures on the building envelope and the use of optimized systems technology.[39]

The BEG consists of three subprograms:

1. Federal funding for efficient buildings - residential buildings (BEG WG)
2. Federal funding for efficient buildings - non-residential buildings (BEG NWG)
3. Federal funding for efficient buildings - individual measures (BEG EM)

Nationwide subsidies are available via KfW and the Federal Office of Economics and Export Control (BAFA). The combination of several programs is possible to make the best use of public subsidies. The application for the BEG EM funding program started on the 1st of January 2021 in the grant variant at BAFA. Currently, the BEG WG and BEG NWG are administered by KfW, however these will also be taken over by BAFA from 2023.

What is KfW?

KfW, or *Kreditanstalt für Wiederaufbau*, is a German development bank that does not have any branches or customer deposits – it is financed almost entirely via the international capital markets. The task of KfW is to realize public orders, such as the promotion of small and medium-sized businesses and start-ups, and granting loans to small and medium-sized enterprises, municipal infrastructure projects, housing developments, and implementation of energy-saving technologies. In 2021, KfW made a total of 107 billion € available for this purpose.

Under the BEG WG and BEG NWG, new building constructions and renovations for residential and non-residential purposes may apply for financing package nr. 261 and nr. 263 from the KfW, respectively. One of the prerequisites for both KfW products is the Sustainable Building Quality Seal (QNG), which must be given by an accredited provider. New constructions of both residential and non-residential buildings will only be granted loans if they meet the *Efficiency Building 40* rating, while loan and subsidy sizes for renovations vary depending on the of *Efficiency Building* rating and *Renewable Energy Class*. Therefore, new constructions built to minimum current GEG standards run the risk that the property will be structurally obsolete shortly after completion - incentivising real estate developers to build to the highest possible efficiency standards now.

[39] Bundesamt für Wirtschaft und Ausfuhrkontrolle (2022). *Bundesförderung für effiziente Gebäude*. BAFA - Förderprogramm im Überblick

KfW product nr. 261- Residential Building Energy Saving[40]

As mentioned previously, the KfW offers funding opportunities for the construction and renovation of residential buildings:

- **New buildings** must reach an *Efficiency Building 40* rating and hold a *Sustainable Building Quality Seal*, with maximum loan capped at 120, 000 euros per building (receiving a 5% repayment subsidy).
- **Renovation** loans and subsidies vary depending on *Efficiency Building* rating and *Renewable Energy Class* achieved post-renovation. Recently a new category of Worst Performing Building (WPB) – was introduced in the funding for energy-efficient retrofits [41]. Buildings with energy performance certificate (EPC) of *Class H*, annual primary energy demand of more than 250 kWh/m^2 or built before 1957 and feature exterior walls with no energetic restoration, are eligible as a WPBs. Since the end of September 2022, WPB owners can receive a bonus of 5 percent, in the form of an additional repayment grant. The bonus is only available for refurbishment to rating of *Efficiency Building 40* and *Efficiency Building 55*. Starting in January 2023, a new program called "Climate-Friendly Construction" will take effect, with the exact details unknown.[42].

Table 2-1: BEG, Systemic funding, Refurbishment of Residential Buildings

Efficiency Building	Repayment grant (as of 28.07.2022)	Maximum amount per housing unit
Efficiency Building 40	20 % of max. 120.000 € loan amount	24.000 €
Efficiency Building 40 Renewable Energy Class	25 % of max. 150.000 € loan amount	37.500 €
Efficiency Building 55	15 % of max. 120.000 € loan amount	18.000 €
Efficiency Building 55 Renewable Energy Class	20 % of max. 150.000 € loan amount	30.000 €
Efficiency Building 70	10 % of max. 120.000 € loan amount	12.000 €
Efficiency Building 70 Renewable Energy Class	15 % of max. 150.000 € loan amount	22.500 €
Efficiency Building 85	5 % of max. 120.000 € loan amount	6.000 €
Efficiency Building 85 Renewable Energy Class	10 % of max. 150.000 € loan amount	15.000 €
Efficiency Historically Protected Building	5 % of max. 120.000 € loan amount	6.000 €
Efficiency Historically Protected Building Renewable Energy Class	10 % of max. 150.000 € loan amount	15.000 €

[40] KfW (2022). *Wohngebäude - Kredit 261.* Wohngebäude – Kredit (261) | KfW

[41] Verband der Immobilienverwalter Deutschland e. V. (2022). *Neue Förderkategorie: Worst Performing Buildings*. Neue Förderkategorie: Worst Performing Buildings | VDIV

[42] Verbraucherzentrale Nordrhein-Westfalen (2022). Zuschüsse fürs Eigenheim: So finden Sie das richtige Förderprogramm. Zuschüsse fürs Eigenheim: So finden Sie das richtige Förderprogramm | Verbraucherzentrale NRW

KfW product nr. 263 – Non-residential Building Energy Saving[43]

As mentioned previously, the KfW offers funding opportunities for the construction and renovation of non-residential buildings:

- **New building** construction and purchase with *Efficiency Building 40* rating (and Sustainability Class) is subsidized by KfW. The eligible costs and thus the maximum credit is based on the net floor area of the building. One receives 2.000 € per square meter of net floor area, but a maximum of 10 million € per project. The repayment subsidy from the KfW Bank is 5 %, which is a maximum of 500.000 €. Additional funding is available for construction monitoring and sustainability certification.
- **Renovations** of all energy-related measures that lead to at least a Efficiency Building 70 rating are subsidized. The eligible costs and thus the maximum credit is based on the net floor area of the building, as for the funding of a new construction. One receives 2.000 € per square meter of net floor area, and a maximum of 10 million € per project for which a new efficiency building level is achieved. The better the efficiency building level of the property after refurbishment, the higher the repayment grant.

Table 2-2: BEG, Systemic funding, Refurbishment of Non-Residential Buildings

Efficiency Building	Repayment grant (as of 28.07.2022)
Efficiency Building 40	20 %
Efficiency Building 40 Renewable Energy Class or Sustainability Class	25 %
Efficiency Building 55	15 %
Efficiency Building 55 Renewable Energy Class or Sustainability Class	20 %
Efficiency Building 70	10 %
Efficiency Building 70 Renewable Energy Class or Sustainability Class	15 %
Efficiency Historically Protected Building	5 %
Efficiency Historically Protected Building Renewable Energy Class	10 %

The German Federal Ministry of Economics and Climate Protection has adjusted the federal subsidy for efficient buildings as of the 28th of July 2022 under the BEG NWG, discontinuing the subsidy for *Efficiency Building 100* in the case of renovations. In addition, the subsidy for gas-fired systems and the associated environmental measures will be discontinued. Maximum loan amounts and repayment subsidies for renovation, new construction and purchase have been adjusted. In general, the subsidies are subject to the availability of budget funds. Accordingly, there is no legal entitlement.

[43] Kreditanstalt für Wiederaufbau (2022). *Nichtwohngebäude – Kredit 263.* Nichtwohngebäude – Kredit | KfW

BAFA Individual Measures[44]

The refurbishment of both residential and non-residential buildings through individual measures is funded through the Federal Support for Efficient Buildings (BEG EM) via grants from BAFA. Since January 2021, insulation measures and window replacement were included. Residential buildings must be older than 5 years, with the maximum of eligible costs for residential buildings capped at 60,000 € per residential unit[45], and minimum investment sum to be 2,000 €, or 300 € for heating optimization. For non-residential buildings, the maximum eligible costs are capped at 1,000 € per m^2 net floor, or a total of max. 5 million €.[46]

Table 2-3: Funding overview - federal funding for efficient buildings (BEG)

	Individual measures for the refurbishment of residential buildings (RB) and non-residential buildings (NRB)	Subsidy rate	Incl. heating exchange bonus
Building envelope	Insulation of exterior walls, roof, floor ceilings and floor areas; replacement of windows and exterior doors; summer thermal insulation	15 %	-
Systems engineering	Installation/replacement/optimization of ventilation systems; RB: installation of "Efficiency Smart Home"; NRB: installation of measurement, control, and regulation technology, room cooling and lighting systems	15 %	-
Heating systems	Solar thermal systems	25 %	-
	Heat pumps	25 %	35 %
	Biomass plants	10 %	20 %
	Innovative heating systems based on RE	25 %	35 %
	RE hybrid heating systems with biomass heating	20 %	30 %
	RE hybrid heating systems without biomass heating	25 %	35 %
	Construction, expansion, conversion of a building network At least 55 % share of RE in the heat mix	25 %	-
	Connection to a building network At least 25 % share of RE in the heat mix	25 %	35 %
	Connection to a heating network At least 25 % share of RE in the heat mix or primary energy factor not exceeding 0.6	25 %	35 %
Heating optimization		15 %	-

44 Bundesamt für Wirtschaft und Ausfuhrkontrolle (2022). *Förderübersicht: Bundesförderung für effiziente Gebäude (BEG)*. BAFA EM

45 Bundesministerium für Wirtschaft und Klimaschutz (2022). *Fördermittel für Gebäudesanierung und Neubauten.* BMWK - Bundesförderung für effiziente Gebäude (BEG) (energiewechsel.de)

46 Bundesministerium für Wirtschaft und Klimaschutz (2022). *Fördermittel für Gebäudesanierung und Neubauten.* BMWK - Bundesförderung für effiziente Gebäude (BEG) (energiewechsel.de)

KfW product nr. 441 – E-Charging Stations

For non-residential buildings, funding is provided for the purchase and installation of new charging stations with a charging capacity of up to 22 kW and an intelligent control system. The prerequisite is that the charging stations use only electricity from renewable energies. Purchase and installation of charging stations that are not publicly accessible are supporting with a grant of up to 900 € per charging point, with maximum grant capped at 45 000 € per location. If the charging stations have several charging points, it is possible to receive a grant of 900 € per charging point, provided that the total cost per charging point exceeds 1.285,71 €. Otherwise, the grant is reduced to 70 % of the total cost. It is not possible to combine this with other public funding. The grant can probably only be applied for until the end of 2022, as the funding will probably be exhausted by then.

Table 2-4: Calculation of the subsidy for e-charging stations

Number of charging points	Flat-rate subsidy = Number of charging points x 900 €	Total cost	Total grant
1	900 €	e.g., 1.000 €	-
1	900 €	min. 1.285,71 €	900 €
2	1.800 €	e.g., 2.000 €	1.400 €
2	1.800 €	min. 2.571,43 €	1.800 €
3	2.700 €	e.g., 3.000 €	2.100 €
3	2.700 €	min. 3.857,14 €	2.700 €
…	…	…	…
10	9.000 €	e.g., 12.000 €	8.400 €
10	9.000 €	min. 12.857,14 €	9.000 €
…	…	…	…
50	45.000 €	e.g., 60.000 €	42.000 €
50	45.000 €	min. 64.285,71 €	45.000 €

Tax incentives for the renovation of buildings[47]

Since 2020, energy-efficient renovation measures have also been possible via a new tax deduction through an amendment to the Income Tax Act. Measures on owner-occupied residential properties 10 years or older. Only measures that are carried out by a specialist company and that meet the requirements of the *Energetische Sanierungsmaßnahme-Verordnung* (ESanMV) permitted for tax purposes. The measures must exceed the minimum technical requirements of the *Gebäude-energiegesetz* (GEG). If these requirements are met, 20% and a maximum of 40,000€ can be reclaimed in the tax return within three years.

[47] Bundesministerium für Wirtschaft und Klimaschutz (2022). *Förderprogramme für Hauseigentümer*. Förderprogramme für Hauseigentümer (energiewechsel.de)

2.2.7 Residential

When carrying out voluntary modernization or new constructions, the GEG requirements must be met. If building components are changed or modernized, the GEG specifies minimum standards that must be achieved through the structural change. If only individual renovation measures are carried out or if only components are renewed, the GEG specifies certain requirements for the heat transfer coefficient of the component. In the case of comprehensive modernization, an overall energy balance (primary energy or greenhouse gas method) is carried out - comparable to a new building.

Table 2-5: GEG 2020 Annex 1: Technical design of the reference building (residential building)

Number	Components/Systems	Reference Design/Value	
		Property (Number 1.1 to 4)	Value
1.1	External wall (including fixtures such as roller shutter boxes), storey ceiling against external air	Heat transfer coefficient	U = 0.28 W/m²K
1.2	External wall against ground, floor slab, walls and ceilings to unheated rooms	Heat transfer coefficient	U = 0.35 W/m²K
1.3	Roof, top storey ceiling, walls to side walls	Heat transfer coefficient	U = 0.20 W/m²K
1.4	Windows, French Doors	Heat transfer coefficient	U_w = 1.3 W/m²K
		Transmittance	g = 0.60
1.5	Skylights, glass roofs and arcade rooflights	Heat transfer coefficient	U_w = 1.4 W/m²K
		Transmittance	g = 0.64
1.6	Light domes	Heat transfer coefficient	U_w = 2.7 W/m²K
		Transmittance	g = 0.64
1.7	External doors; doors against unheated rooms	Heat transfer coefficient	U_w = 1.8 W/m²K
2	Components according to items 1.1 to 1.7	Thermal bridge surcharge	ΔUWB = 0.05 W/m²K
3	Solar heat gains via opaque components	How the building is to be constructed	
4	Air tightness of the building envelope	Rated value n_{50}	DIN V 4108-6: 2003-06: with leak test DIN V 18599-2: 2018-09: according to category 1
5	Sun protection device	No sun protection device mandated	
6	Heating system	Heat generation by condensing boilers (improved, for calculation according to § 20(1) after 1994), natural gas, installation: - for buildings up to 500 m2 useful building area within the thermal envelope - for buildings with more than 500 m2 useful building area outside the thermal envelope Design temperature 55/45 °C, central distribution system within the heat-transferring enclosure surface, internal	

		lines and connecting lines, standard line lengths according to DIN V 4701-10: 2003-08 Table 5.3-2, pump designed for demand (controlled, Δp const), pipe network only statically hydraulically balanced. Heat transfer with free static heating surfaces, arrangement on normal external wall, thermostatic valves with proportional range 1 K according to DIN V 4701-10: 2003-08 or P-controller (not certified) according to DIN V 18599-5: 2018-09
7	Domestic hot water heating system	Central water heating Joint heat generation with heating system according to number 6 When calculated in accordance with § 20(1): General boundary conditions according to DIN V 18599-8: 2018-09 Table 6, solar system with flat-plate collector designed after 1998 and storage tank designed according to DIN V 18599-8: 2018-09 Section 6.4.3 When calculated in accordance with § 20(2): Solar system with flat-plate collector for exclusive domestic hot water heating in accordance with the specifications as per DIN V 4701-10: 2003-08 Table 5.1-10 with storage tank indirectly heated (standing), same installation as heat generator, - Small solar system with AN ≤ 500 m2 (bivalent solar storage tank) - Large solar system for AN > 500 m2 Distribution system with circulation, within the heat transferring enclosure surface, internal lines, common installation wall, standard line lengths according to DIN V 4701-10: 2003-08 Table 5.1-2
8	Cooling	No cooling
9	Ventilation	Central exhaust air system, not demand-controlled with controlled DC fan, - DIN V 4701: 2003-08: System air change, n_a = 0.4 h-1 - DIN-V 18599-10: 2018-09: Use-related minimum outdoor air exchange rate, n_{use} = 0.55 h-1
10	Building Automation	Class C according to DIN V 18599-11:2018-09

2.2.8 Offices

Like residential buildings, new or significantly refurbished office buildings must comply with GEG standards as far as the energy condition of the respective building is concerned. Further, an Energy Performance Certificate (EPC) must be issued based on the energy characteristics of the building. The relevant minimum standards for building energy performance are listed below.

Table 2-6: GEG 2020 Annex 3: Technical design of the reference building (non-residential building)

Number	Components/Systems	Reference Design/Value		
		Property (Number 1.1 to 1.13)	Heating setpoint ≥ 19°C	Heating setpoint 12°C to 19°C
1.1	External wall (including fixtures such as roller shutter boxes), storey ceiling against external air	Heat transfer coefficient	$U = 0.28\ W/m^2K$ $\bar{U} = 0.22\ W/m^2K$	$U = 0.35\ W/m^2K$ $\bar{U} = 0.28\ W/m^2K$
1.2	Curtain wall (see also number 1.14)	Heat transfer coefficient	$U = 1.4\ W/m^2K$ $\bar{U} = 1.2\ W/m^2K$	$U = 1.9\ W/m^2K$ $\bar{U} = 1.5\ W/m^2K$
		Thermal transmit.	g = 0.48	g = 0.60
		Light transmittance	$TV_{D65,SNA} = 0.72$	$TV_{D65,SNA} = 0.78$
1.3	Walls against ground, floor slab, walls and ceilings to unheated rooms	Heat transfer coefficient	$U = 0.35\ W/m^2K$	$U = 0.35\ W/m^2K$
1.4	Roof, top storey ceiling, walls to offsides	Heat transfer coefficient	$U = 0.20\ W/m^2K$	$U = 0.35\ W/m^2K$
1.5	Glass roofs	Heat transfer coefficient	$U_w = 2.7\ W/m^2K$ $\bar{U} = 2.0\ W/m^2K$	$U_w = 2.7\ W/m^2K$ $\bar{U} = 2.5\ W/m^2K$
		Thermal transmit.	g = 0.63	g = 0.63
		Light transmittance	$TV_{D65,SNA} = 0.72$	$TV_{D65,SNA} = 0.78$
1.6	Light bands	Heat transfer coefficient	$U_w = 2.4\ W/m^2K$ $\bar{U} = 2.0\ W/m^2K$	$U_w = 2.4\ W/m^2K$ $\bar{U} = 2.5\ W/m^2K$
		Thermal transmit.	g = 0.55	g = 0.55
		Light transmittance	$TV_{D65,SNA} = 0.48$	$TV_{D65,SNA} = 0.48$
1.7	Light domes	Heat transfer coefficient	$U_w = 2.7\ W/m^2K$ $\bar{U} = 2.0\ W/m^2K$	$U_w = 2.7\ W/m^2K$ $\bar{U} = 2.5\ W/m^2K$
		Thermal transmit.	g = 0.64	g = 0.64
		Light transmittance	$TV_{D65,SNA} = 0.59$	$TV_{D65,SNA} = 0.59$
1.8	Windows, French doors (see also number 1.14)	Heat transfer coefficient	$U_w = 1.3\ W/m^2K$ $\bar{U} = 1.2\ W/m^2K$	$U_w = 1.9\ W/m^2K$ $\bar{U} = 1.5\ W/m^2K$
		Thermal transmit.	g = 0.60	g = 0.60
		Light transmittance	$TV_{D65,SNA} = 0.78$	$TV_{D65,SNA} = 0.78$
1.9	Skylight (see also number 1.14)	Heat transfer coefficient	$U_w = 1.4\ W/m^2K$ $\bar{U} = 1.2\ W/m^2K$	$U_w = 1.9\ W/m^2K$ $\bar{U} = 1.5\ W/m^2K$
		Thermal transmit.	g = 0.60	g = 0.60
		Light transmittance	$TV_{D65,SNA} = 0.78$	$TV_{D65,SNA} = 0.78$
1.10	External doors; doors against unheated rooms; gates	Heat transfer coefficient	$U = 1.8\ W/m^2K$	$U = 2.9\ W/m^2K$

1.11	Components 1.1 and 1.3 to 1.10	Thermal bridge surcharge	ΔU_{WB} = 0.05 W/m²K	ΔU_{WB} = 0.01 W/m²K
1.12	Building air tightness	Category according to DIN V 18599-2 Table 7	Category 1	Category 1
1.13	Daylight supply with sun or glare protection or with sun and glare protection	Daylight supply factor$_{CTL,Vers,SA}$ according to DIN18599-4	No sun or glare protection available: 0.7 Glare protection available: 0.15	No sun or glare protection available: 0.7 Glare protection available: 0.15
1.14	Sun protection device	For the reference building, the actual solar protection device of the building to be erected shall be assumed; if applicable, it results from the requirements for summer thermal insulation according to § 14 or from requirements for glare protection. If solar control glazing is used for this purpose, the following characteristic values are to be applied for this glazing: Instead of the values in number 1.2: - Thermal transmittance g = 0.35 - Light transmittance $TV_{D65,SNA}$ = 0.58 Instead of the values in numbers 1.8 and 1.9: - Thermal transmittance g = 0.35 - Light transmittance $TV_{D65,SNA}$ = 0.62		
2	Solar heat gains via opaque components	As with the building to be constructed		
3.1	Type of lighting	Direct/indirect with electronic ballast and linear fluorescent lamp		
3.2	Lighting control	<u>Presence control:</u> - In zones of uses 4, 15 to 19, 21 and 31* with presence detector - Incidentally: manual override <u>Light control/daylight-dependent control:</u> - In zones of uses 5, 9, 10, 14, 22.1 to 22.3, 29, 37 to 40* constant light control according to DIN V 18599-4: 2018-09 Section 5.4.6 - In zones of uses 1 to 4, 8, 12 28, 31 and 36* with daylight-dependent control, control type “dimmed, not switching off” in accordance with DIN V 18599-4: 2018-09 section 5.5.4 (including constant light control) - Incidentally: manual override *Uses according to Table 5 of DIN V 18599-10: 2018-09		
4.1	Heat generator (room height ≤4m)	- Condensing boiler (improved, after 1994) according to DIN V 18599-5:2018-09 - Natural gas - Installation outside the thermal envelope - Water content > 0.15 l/kW		
4.2	Heat distribution (room heights ≤4m)	<u>For static heating and recirculation heating (decentralised reheating in AHU):</u> - Two-pipe network		

		- External distribution pipes in the unheated area - Internal risers and connecting pipes - System temperatures 55/ 45 C - Exclusively statically hydraulically balanced - Pump design on-demand/intermittent operation - No overflow valves - Reference case pipe length and ambient temperatures as per DIN V 18599-5:2018-09 For central air handling units: - Two-pipe network, system temperature 70/55 C - Exclusively statically hydraulically balanced - Pump deign on-demand - Reference case pipe lengths and locations the same as the proposed building
4.3	Heating Transfer (room heights ≤4m)	Static heating - Free heating surfaces on the outer wall (if arrange in front of glass surfaces with radiation protection) - Exclusively statically hydraulically balanced - P-controller - No auxiliary energy Recirculation heating (reheating in air handling unit): - Control variable room temperature - High control quality
4.4	Heat generation/transfer (room heights > 4m)	Decentralised heating system Heat generator according to DIN V 18599-5: 2018-09 Table 52: - Decentralised warm air heater - Non-condensing - Power 25 to 50 kW per unit - Energy source natural gas - Capacity control 1 (single-stage or multi-stage/ modulating without adjustment of the combustion air volume) Heat transfer according to DIN V 18599-5:2019-09 Table 16 and Table 22: - Centrifugal fan, outlet horizontal - Without warm air return - P-controller for room temperature
5.1	Centralised hot water	Heat generator: General boundary condition according to DIN V 18599-8: 2018-09 Table 6, solar thermal system with flat-plate collector (post 1998) for exclusive domestic hot water heating with standard values according to Table 19 or section 6.4.3, but deviating for centrally supplied hot water net floor areas over 3000m2. Residual demand via heat generator of heating system.

		<u>Heat storage:</u> Bivalent storage tank installed outside the thermal envelope according to DIN V 18599-8: 2018-09 Section 6.4.3. <u>Heat distribution:</u> Reference case to have same pipe length and pipe location as the proposed building.
5.2	Decentralised hot water	Hydraulically controlled electric instantaneous water, one tap and 6 meter pipe length per unit for building zones with a hot water demand of no more than 200 Wh / m^2 per day.
6.1	Exhaust air	Specific power consumption fan_{PSFP} = 1.0 kW / (m^3/s)
6.2	Supply and exhaust air	<u>Air volume control:</u> - Supply and exhaust air system is provided for zones of uses 4, 8, 9, 12, 13, 23, 24, 35, 37 and 40* - Designed with demand-dependent air volume control category IDA-C4 in accordance with DIN V 18599-7: 2018-09 Section 5.8.1 <u>Specific power consumption:</u> - Supply air fan_{PSFP} = 1.5 kW / (m^3/s) - Exhaust air fan_{PSFP} = 1.0 kW / (m^3/s) - Extended PSFP surcharges according to DIN EN 16798-3: 2017-11 section 9.5.2.2 can be credited for HEPA filters, gas filters as well as heat recovery components of classes H2 or H1 according to DIN EN 13053:2007-11. <u>Heat recovery:</u> - Via Plate heat exchanger - Degree of temperature change $\eta_{t, comp}$ = 0.6 - Supply air temperature 18 C - Pressure ratio P = 0.4 <u>Air duct routing:</u> - Inside the building <u>Cooling function:</u> - Designed for 6/12 C - No indirect evaporative cooling - *Uses according to Table 5 of DIN V 18599-10: 2018-09
6.3	Air humidification	Reference case air humidification equipment is assumed as proposed building
6.4	Air-only air conditioners	<u>Cooling load-controlled variable volume flow system</u>: - Pressure ratio fP = 0.4 - Constant inlet air pressure - Air duct routing inside the building
7	Room cooling	<u>Cooling system</u>: - Cold water fan coil unit - Under sill unit - Cold water temperature 14/18C

		Cold water circuit room cooling: - Overflow 10% - Specific power $P_{d,spez}$ = 30 W_{el} / $kW_{cooling}$ - Hydraulically balanced - Controlled, hydraulically decoupled pump - Season, night and weekend shut-off according to DIN V 18599-7: 2018-09 Annex D
8	Refrigeration	Producer: - Piston/scroll compressor multi-stage switchable - R134a - Outdoor air cooled - No storage - Age factor $f_{c,b}$ = 1.0 - Free cooling factor f_{FC} = 1.0 Cold water temperature - For more than 5000 m^2 net floor area conditioned by means of space cooling 14/18 C - Incidentally: 6/12 C Water circuit producer including AHU cooling: - Overflow 30% - Specific power $P_{d,spez}$ = 30 W_{el} / $kW_{cooling}$ - Hydraulically balanced - Unregulated, hydraulically decoupled pump - Seasonal, night and weekend shut-off according to DIN V 18599-7: 2018-09 Annex D - Distribution outside the conditioned zone - Only 50% of primary energy demand for cooling system and function of the ventilation and air-conditioning system may be counted for zones of uses 1 to 3, 8, 10, 16, 18 to 20 and 31* *Uses according to Table 5 of DIN V 18599-10: 2018-09
9	Building Automation	Class C according to DIN V 18599-11: 2018-09

2.2.9 Public

Under the Federal Cabinet "Energy efficiency specifications for climate-neutral new buildings and extensions and building refurbishments by the federal government" resolution, public sector buildings are to function as role models for functional, cost effective, energy efficient and sustainable construction[48]. For this reason, the federal government has decided that the current minimum requirements for federal buildings should be exceeded: new buildings must be at least 60 percent more energy efficient than the legal requirements for new construction, whereas building renovations are to be at least 45 percent more energy efficient. The energy efficiency retrofits of federal buildings are to be implemented together with modernization measures that are due anyway. For already existing, leased federal buildings, the high requirements are also to apply from 2025.

[48] Die Bundesregierung (2021). *Klimaschutz bei Bundesbauten – Vorbild für klimaneutrale Gebäude*. Klimaschutz bei Gebäuden des Bundes (bundesregierung.de)

Assessment for Sustainable Building of Federal Buildings (BNB)

The Assessment for Sustainable Building of Federal Buildings (BNB) is like Leadership in Energy and Environmental Design (LEED) or German Sustainable Building Company (DGNB) certification processes, where extensive criteria are used to judge the sustainability of public buildings. Under the Guidelines for Sustainable Building (LFNB), three 'modules' exist for each phase of a building's life – construction (suffixed with N), use and operation (suffixed with B), and complete refurbishment (suffixed with K). Variations in the criteria are informed by the use type of the building, with the following uses established:

- Federal Office and Administrative Buildings (BNB_B)
- Federal Educational Buildings (BNB_U)
- Federal Laboratories (BNB_L)
- Inter-company Vocational Training Facilities (BNB _ÜBS)
- Federal Outdoor Facilities (BNB_AA)

For example, the criteria for the renovation of federal office and administration buildings would be labelled 'BNB_BK'. The variants are limited, with BNB systems established for the new construction of all use types, but only offices and educational buildings being subject to refurbishment and/or operation assessment. Regardless of variants, all buildings are assessed via five categories: ecological quality, economic quality, social-cultural and functional quality, technical quality, process quality and site characteristics. All federal buildings must pass the relevant BNB standard, however, state/municipal buildings (representing the large majority of publicly owned buildings), must only adhere to the strict GEG standards mentioned earlier – BNB is voluntary.

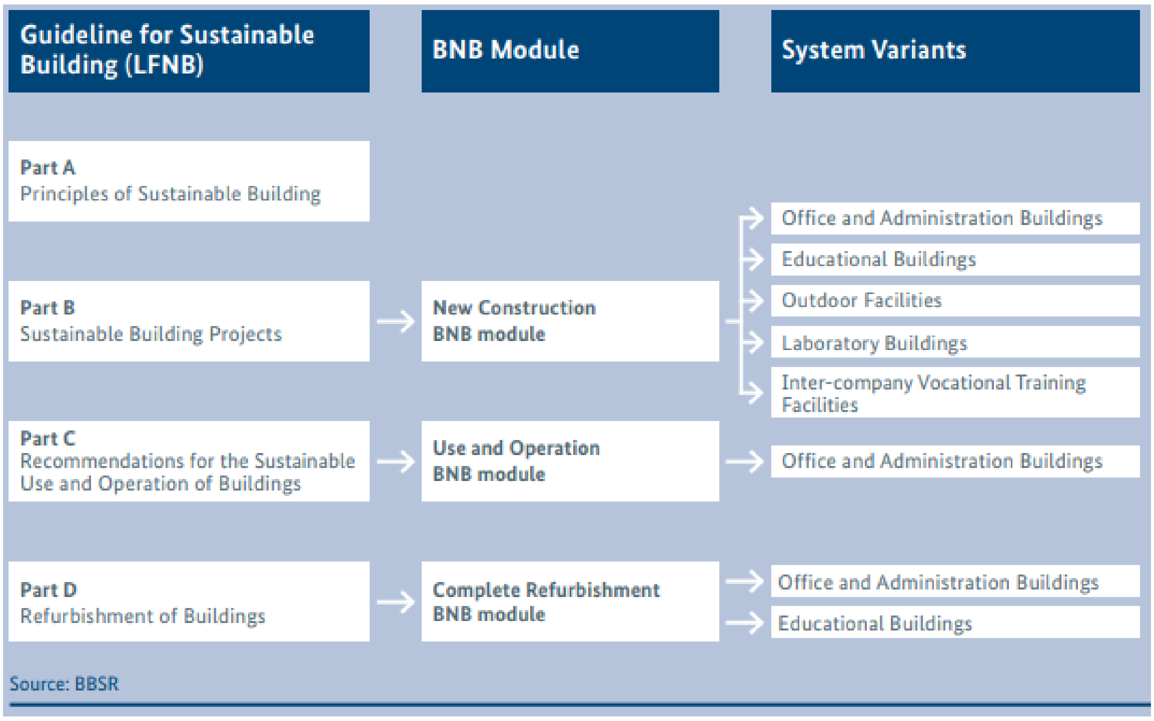


Figure 2-6: Various modules and variants of the BNB system

2.3 Energy market rules and tariffs

The operation of commercial and residential buildings in Germany accounts for a large fraction of energy (35 percent of final energy consumption). Due to the cold winters and relatively short, mild summers of Germany, space heating is the predominant segment of Germany's building energy consumption[49,50], with approximately 27% of total final energy consumption. Energy efficiency regulation has seemingly reduced the fraction of space heating required by the commercial sector by approximate 14% between 2008 and 2019, while the residential sector has seen a less dramatic heating fraction reduction of around 5% in the same timeframe (Figure). Industrial need for refrigeration has increased significantly since 2008, while its fraction of space heating has also reduced significantly (down 23% since 2008). All three sectors feature reductions in absolute final energy consumption, with commercial down 9%, residential down 5%, and industrial down 3% from 2008 [50].

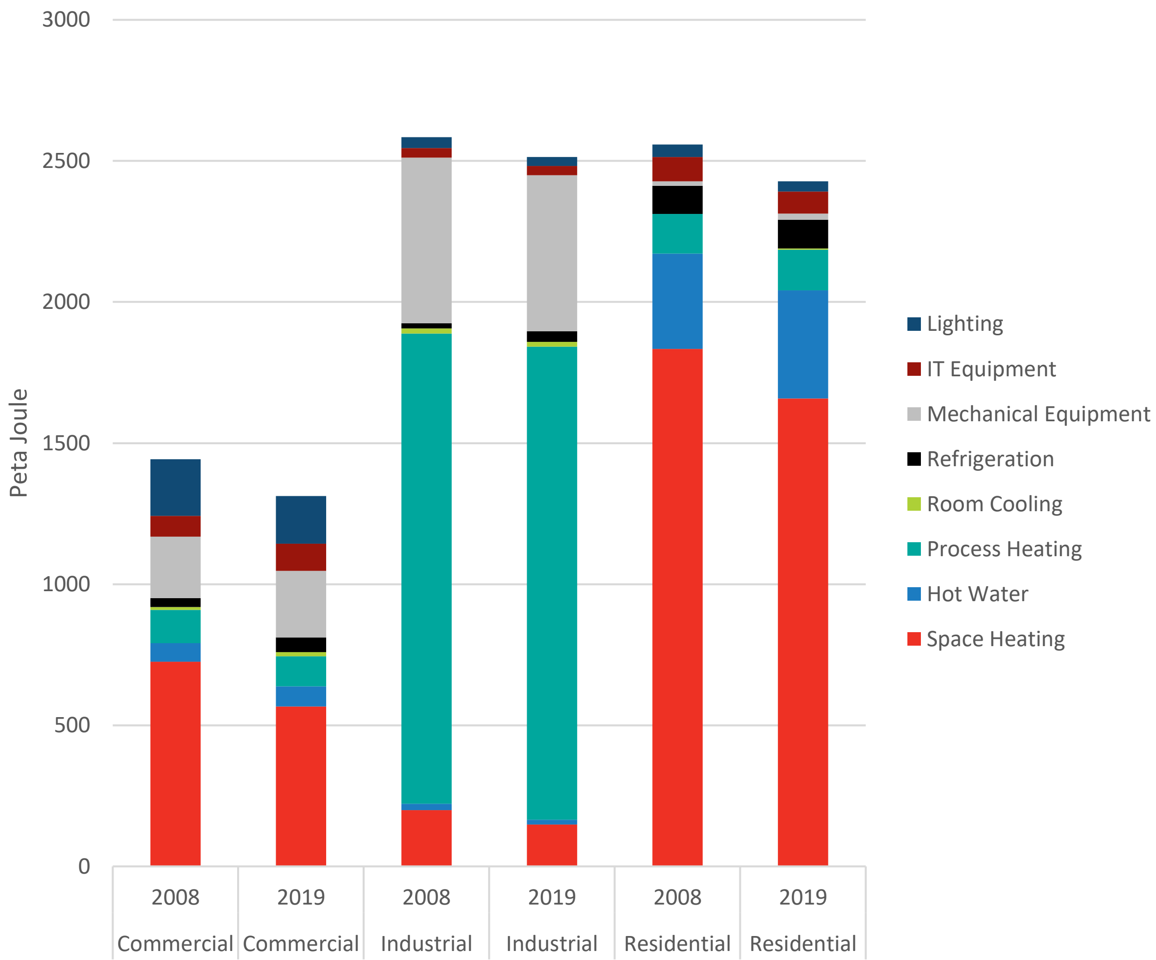


Figure 2-7: Final energy by end use per sector (BMWK 2021)[50]

[49] International Energy Agency (2020). Germany 2020 – Energy Policy Review

[50] Bundesministerium für Wirtschaft und Klimaschutz (BMWK) (2021). Energieeffizienz in Zahlen 2021

Historically, national coal reserves and oil imports provided the majority of Germany's total primary energy supply; however, this has shifted to less carbon intensive sources, with a marked increase in imported natural gas, bioenergy and waste, and other renewables [49]. Despite this growth, fossil fuels still represent the bulk of overall primary energy supply (roughly 75%), with wind, solar and hydroelectric power constituting less than 10% combined in 2018 [49]. In the building sector, direct fossil fuel use makes up roughly half of final energy supply across commercial, industrial, and residential buildings. The commercial building sector has seen a substantial decrease in the use of crude oil derivatives since 2008, with increasing environmental heat sources and electricity - signaling a switch to heat pumps. The residential and industrial sectors have shown a similar, but less dramatic trend, replacing oil with heat pumps (more so in residences) and district heating. Gas still plays a very significant role across all building sectors, however, price pressures due to lack of European supply may change this in commercial and residential sectors, where conversion to other energy carriers is relatively cheaper.

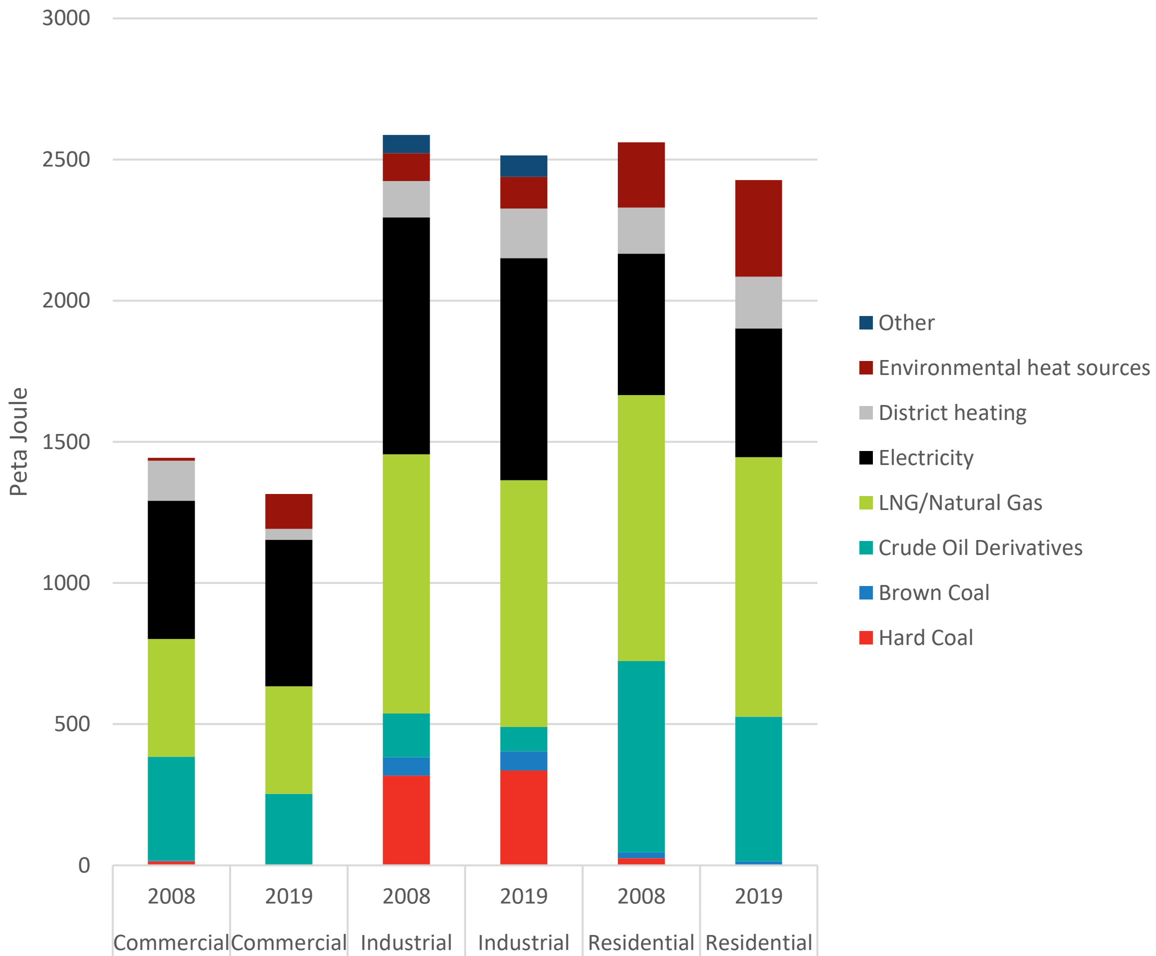


Figure 2-8: Final energy carriers by sector (BMWK 2021)[50]

2.3.1 Taxes and fees

The Klimaschutzprogramm, or “Climate Protection Program”, of 2019 introduced the pricing of CO2 equivalent emissions for transport and heating – 25 euros per ton from January 2021 to an expected 55 euros in 2025. According to the Federal Office of Environment:

“Businesses and citizens who use fossil fuels for heating or driving, for example, do not participate directly in national emissions trading. Instead, those who bring these fuels into the fiscal economy are obliged to participate…. For each tonne of CO2 produced by the combustion of these fuels, the party placing the fuel on the market must acquire a corresponding emissions certificate and surrender it to the DEHSt.”

Due to the escalating prices of energy in Germany, the federal government has taken actions to reduce taxes and surcharges of energy stocks. From the 1st October 2022 until the 31 March 2024, a VAT rate of 7%, instead of the usual 19%[51] will be applied to gas and heating suppliers in an aim to quell the cost of energy for the public. Similarly, since July 1st 2022, the Renewable Energy Sources Act (EEG) surcharge for electricity has been reduced to zero, with the Energy Financing Act completely abolishing the EEG surcharge from 1st January 2023. These measures have stabilized prices temporarily, however, the federal government walks a tightrope. Slashing prices via tax cuts or price ceilings impacts government/energy importer revenue and incentivizes less restrictive use of scarce resources. Conversely, soaring prices could plunge the economy into a recession and leave some of the population in energy poverty. Until now, the government has had little time to develop a medium-term plan. Therefore, the outlook and impact on markets remains uncertain.

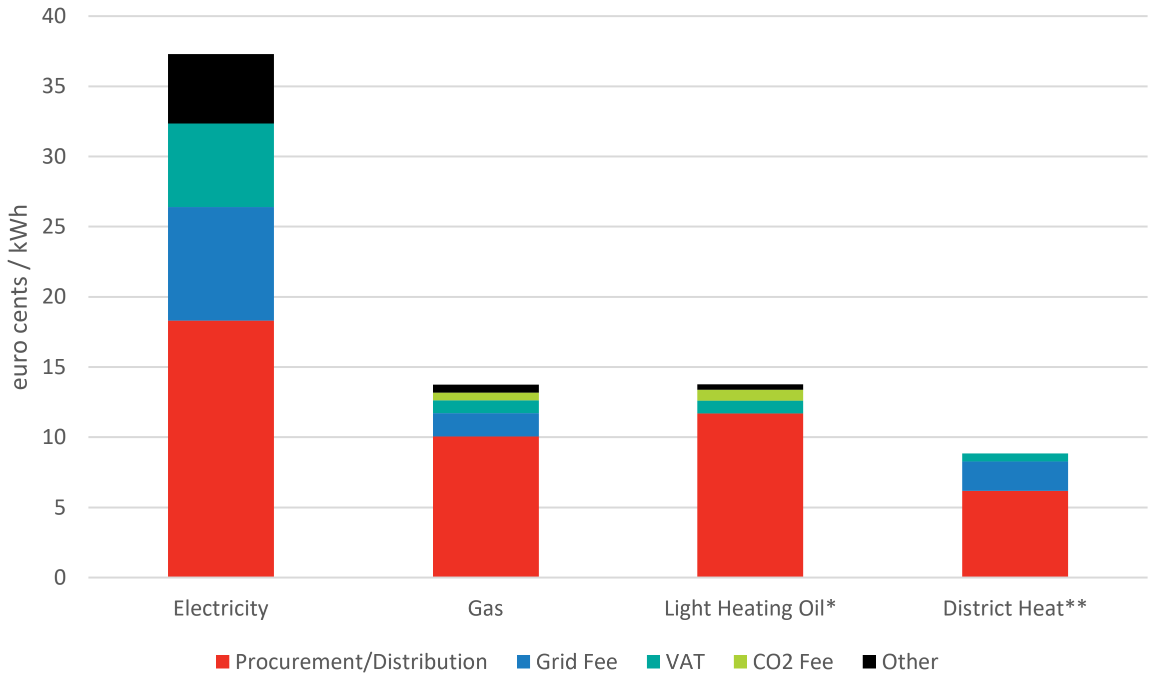


Figure 2-9: Price components of household energy carriers
**2022 value, CO2 fee calculated using 11 kWh / liter and 0.31 kg CO2 equiv. / kWh*
*** 2021 value, grid fee assumed 2.09 euro cents / kWh*

[51] Bundesregierung (2022). Gas surchage FAQ

2.3.2 Subsidies

Federal Funding For Efficient Heating Networks (BEW)

The Bundesförderung für effiziente Wärmenetze (BEW), or "Federal Funding for Efficient Heating Networks", (effective from 15th September 2022) is intended to work with the Federal funding for Efficient Buildings Individual Measures (BEG EM) by developing climate-neutral heating networks[52]. Operating cost subsidies are granted for the generation of renewable heat from solar thermal and heat pumps fed into both new and transformed heating networks. Companies, municipal companies/operations as well as registered associations and cooperatives may all apply for the following sequential funding modules:

- *Module 1: The Promotion of Transformation Plans or Feasibility Studies*
- *Module 2: The Promotion of a Heating Network Construction*
- *Module 3: The Promotion of Individual Measures in a Heating Network*
- *Module 4: Operational Cost Subsidies for Solar Thermal Systems and Heat Pumps*

The subsidy is subject to several restrictions, which are regulated by the BAFA application process. The networks must supply heat to more than 16 buildings or more than 100 residential units. Transformation plans are intended to show the conversion of existing heating network systems toward a carbon-neutral heating network by 2045, while new buildings must supply a feasibility study which demonstrates at least 75 percent renewable energy or waste heat use. Distinctions are made between the new construction or the transformation of a carbon-neutral heating network (Module 2) and between short-term individual measures that were not outlined in the feasibility or transformation plan (Module 3). Further, different processes are defined for heating networks that can be built or completely transformed in a maximum period of four years and those which require a longer period to reach carbon-neutrality.

Table 2-7: BEW Module Summary

Module	Scope	Subsidies
1	Planning: Feasibility studies, transformation plans, preparation of planning services and documents Testing: Expert reports, test drillings, thermal reaction tests or similar (permit fees excluded)	50% of eligible expenses Max. 2 million euro Within 1 to 2 years
2	Network Construction: Heating network material and construction cost subsidization	40% of eligible expenses Max. 100 million euros Within 4 to 6 years Subsidy limited to profitability gap
3	Individual Measures: Solar thermal, heat pumps, biomass boilers, heat accumulators, pipelines for the connection/expansion of renewable energy producers and integration of waste heat, heat transfer stations	40% of eligible expenses Max. 100 million euros 2-3 years Subsidy limited to profitability gap
4	Operation: Only available for systems installed under the application of Module 2 or 3	Not yet available

[52] BAFA (2022). Bundesförderung für effiziente Wärmenetze (BEW).

KfW product nr. 270

The KfW Bank's financial product nr. 270 – Renewable Energies - provides loans for power and heat generation plants as well as grids and storage facilities[53]. Private individuals, companies and public institutions can obtain the low-interest loan. However, private individuals must feed a portion of the electricity or heat generated into the respective grid – limiting the general scope to electricity producing devices (subsidies for solar thermal systems and heat pumps for residential buildings can be applied for with the help of KfW nr. 261). The following investments are financed with the help of the financial product:

1. Construction, expansion, and acquisition of renewable energy systems, including the associated costs for planning, project planning and installation. The systems must meet the requirements of the law for the expansion of renewable energies.
    - PV systems on roofs, on facades or on open spaces
    - Hydroelectric power plants up to a size of 20 MW
    - Plants for the generation of electricity from wind power
    - Plants for electricity and heat generation in combined heat and power plants (CHP plants) based on solid biomass, biogas or geothermal energy
    - Plants for the production, processing and injection of biogas
    - Battery storage
2. Construction, expansion, and acquisition of plants only for heat generation based on renewable energies
3. Heating/cooling networks and heating/cooling storage systems fed by renewable energies
4. Flexibilization of electricity demand and supply, digitalization of the energy transition with the aim of integrating renewable energies into the energy system in a system-compatible manner
    - e.g., electricity storage facilities (power-to-x technologies), load management, measurement and control systems, as an individual measure or retrofit
5. Contracting project and modernization with performance increase

The loan amount can be up to 50 million euros per project and thus cover up to 100% of the investment costs. The interest rates and terms of the subsidized loans for electricity and heat must be taken from a table of conditions, with a 2-year minimum term. The individual interest rate is calculated based on location, economic circumstances, and the quality of the collateral by the house bank. During the repayment-free period, only interest is paid. Thereafter, equal quarterly instalments plus interest are paid on the loan amount still to be repaid. The loan can also be fully or partially repaid off-schedule. A combination with other public subsidies is possible.

[53] Kreditanstalt für Wiederaufbau (2022). *Erneuerbare Energien – Standard*. Erneuerbare Energien – Standard (270) | KfW

Mieterstrom

Mieterstrom, or 'landlord-to-tenant' electricity, is electricity generated by solar systems of a building and supplied and consumed directly, i.e. without being fed through the grid, to tenants in this building or in the same neighbourhood. In contrast to the purchase of electricity from the grid, there are no grid fees, grid surcharges, electricity tax or concession fees. However, tenant electricity models cause additional expenses for the sales provider - metering and billing. A Mieterstrom subsidy of solar 'landlord-to-tenant' electricity is in place to close the existing profitability gap[54]. For landlords, the subsidy is intended to make the offer of tenant electricity more economically attractive.

The subsidy is limited to residential or partial commercial buildings (minimum of 40% commercial) and a maximum installed PV capacity of 1 MW (according to EEG 2023). 'Landlord-to-tenant' electricity for commercial buildings would be called PV-Direktlieferung, gewerblicher Mieterstrom, or "commercial landlord-to-tenant" electricity would not be subsidized[55].

To implement 'Landlord-to-tenant', the landlord can choose between two basic models: either they look for a **tenant electricity contractor** or operate the photovoltaic system in the so-called **tenant electricity enabling** model. Ultimately, there are always three roles that must be regulated in a tenant electricity model: the role of the investor and owner of the PV system, the role of the operator of the PV-system, and the role of the energy consumer.

In the contracting model, the tenant electricity contractor takes over the operation and usually also the financing of the solar system. In principle, the landlord only provides the space for the system technology and receives a lease for it. He does not need any know-how in the energy market and avoids a trade tax liability[56]. However, the contracting method is difficult to implement for projects with Building Integrated Photovoltaics (BIPV), such as façade integrated PV, PV-Pergolas, or PV-Balustrades which are included into the design from early stage and the investment was not performed by the contractor and could therefore not easily be integrated in a contracting model.

In the enabling model, the operator must have know-how in the energy market. According to the Energy Industry Act (EnWG), they must fulfil the requirements of the energy supplier market role and supply the entire electricity to the tenants. The operator therefore enters contracts for consumers with conventional electricity supply companies, which thus take over the residual supply. But even in this model, the landlord does not have to fill all roles in the complex structure of tenant electricity and employ a professional 'landlord-to-tenant' electricity provider. For buildings with only a few tenants, the transaction costs, metering, and billing would be high relative to the electricity sales. Professional 'landlord-to-tenant' electricity providers from the energy industry therefore usually only offer their services for larger multi-tenant buildings. Therefore, small-scale landlords have to take on the role as an energy supplier and are exposed to a trade tax liability and need know-how in the energy market.

The higher feed-in tariff for full feed-in compared to surplus feed-in instantiated by the EEG 2023 changes the consideration of taking on the greater expense of offering 'landlord-to-tenant' electricity and selling it to tenants. However, system operators can theoretically switch between full and surplus feed-in annually by notifying the local grid operator.

[54] BMWK (2022) Häufig gestellte Fragen zum Mieterstrom.
[55] Node.energy (2022). PV-Direktlieferung– Mieterstrom für Industrie & Gewerbe
[56] Solarserver (2022). Mieterstrom

Renewable Energy Sources Act – Feed-in Tariff

The gradual reduction of the feed-in tariff for solar electricity and the switch to tendering procedures had stopped the investment boom in photovoltaics almost 10 years ago. In 2001, the feed-in tariff for solar systems with less than 10 kWp was 50,6 cents per kWh, significantly higher than the electricity price (avg. 14,3 euro cents per kWh) – incentivizing massive PV expansion. After the investment peak of 19.4 billion was reached in 2010 and tariff rates dropped, investments declined significantly every year. At the low point of the solar crisis in 2014, only €1.45 billion was invested in the construction of new photovoltaic plants. Since then, investments in new PV plants have been slowly but steadily increasing again to €4.57 billion in 2021. Photovoltaics now account for the largest share of the renewable energy market, at 34% of the total volume of €13.4 billion (+ solar thermal 4%)[57].

The 2022 amendment to the Erneuerbare-Energien-Gesetz 2023 (EEG 2023), or "German Renewable Energy Sources Act", outlines a massive expansion of renewable energies in alignment with renewable energy goals. From 2026, the ambitious expansion target is 22 gigawatts of new PV installations - around half of them on roofs. Promoting this expansion, the EEG will no longer provide subsidies for self-consumption of electricity, favoring a higher feed-in-tariff. Homeowners with a PV system can decide anew before each calendar year with the responsible network operator which of the following options should apply[58]:

- **Surplus feed-in**: Surplus electricity is fed into the grid at a fixed tariff of 8.2 euro cents per kWh for the first 10 kWp installed, and 7.1 cents per kWh for larger capacities.
- **Full feed-in**: Full feed-in systems may not use the self-generated electricity, instead solely selling electricity back to the grid for a tariff: 13 euro cents per kWh for the first 10 kWp installed and 10.9 euro cents per kWh for larger capacities.

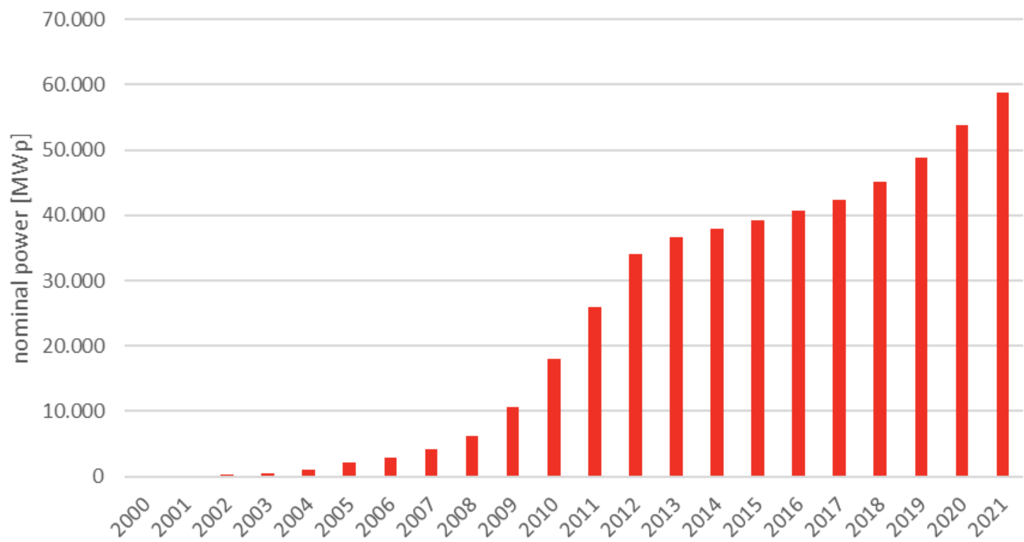


Figure 2-10: Development of installed PV-Power in Germany[59]

[57] Strom-Report (2022): Photvoltaik in Deutschland. [Aktuelle Zahlen & Fakten zur Photovoltaik in Deutschland (strom-report.de)]

[58] mein-eigenheim (2022). *Photovoltaik: Die neuen Regeln für die Einspeisevergütung 2022*. [Photovoltaik: Die neuen Regeln für die Einspeisevergütung 2022 - Mein Eigenheim (mein-eigenheim.de)]

[59] Statista (2022). Installierte Leistung (kumuliert) der Photovoltaikanlagen in Deutschland in den Jahren 2000 bis 2021. [Installierte Leistung aller Photovoltaikanlagen in Deutschland bis 2021 | Statista]

Along with higher grid electricity prices, the EEG policies feature better incentives for PV installations. Due to the complete abolition of self-consumption remuneration, leased consumption meters can be omitted for existing PV systems from 2023, with billing significantly simplified. The high subsidy for full feed-in is also intended to encourage more PV systems to be installed on roofs that have little or no self-consumption. Up to now, photovoltaics has simply not been profitable on these roofs. The new regulations also allow the simultaneous commissioning of a self-consumption system and a full feed-in system on the same building. In this way, one system can be designed for high self-consumption and the full potential of the roof space can still be used with a second system. Because both systems have to be technically separated (e.g. by their own inverters), this solution is rather less suitable for domestic systems.

In principle, the operation of a PV system is not subject to trade tax. However, if the PV is installed on a commercial building, it must be reported to the trade licensing office. Regardless of the threshold value, there is always an obligation to register for tax with the tax office as soon as the system is installed on a commercially used site. The type of business to be registered is left to the owners by law[60].

2.3.3 Electricity

While direct fossil fuel use constitutes approximately half of all energy use in industry, commercial and residential sectors, the amended Federal Climate Protection Act (2021) is pushing for electrification at accelerated rates. The Bundesministerium für Wirtschaft und Klimaschutz, or "Federal Ministry of Economy and Climate", has continuously revised upward the forecasted 2030 electricity consumption, from 580TWh (in 2020) to 655 TWh (in 2021)[61] to 750 TWh (in 2022)[62]. While promising improvements in efficiency, pushes to electrify space/process heating and transport may lead to significant increases in demand over a relatively short time span. Adding to this pressure, base load energy and energy storage remain core issues with intermittent and unpredictable renewable energy sources (such as wind and photovoltaics). Currently, renewable energy supplies approximately half of electricity generation, with Renewable Energy Sources Act (EEG 2023) pushing for accelerated exploitation of wind energy and solar photovoltaics[63]. However, the sudden increase in baseload demand could result in renewables expansion unable to keep pace in the short term. Paradoxically, this may force the German government to continue the exploitation of fossil fuels for electricity production – all in the pursuit of carbon emission reductions.

[60] Firma.de (2022). Photovoltaik und Gewerbe: Was muss ich beachten?. Photovoltaik und Gewerbe: Was muss ich beachten? – firma.de

[61] BMWK - Altmaier legt erste Abschätzung des Stromverbrauchs 2030 vor

[62] More energy from renewable sources | Federal government (bundesregierung.de)

[63] BMWK - Federal Ministry for Economic Affairs and Energy More wind energy at sea

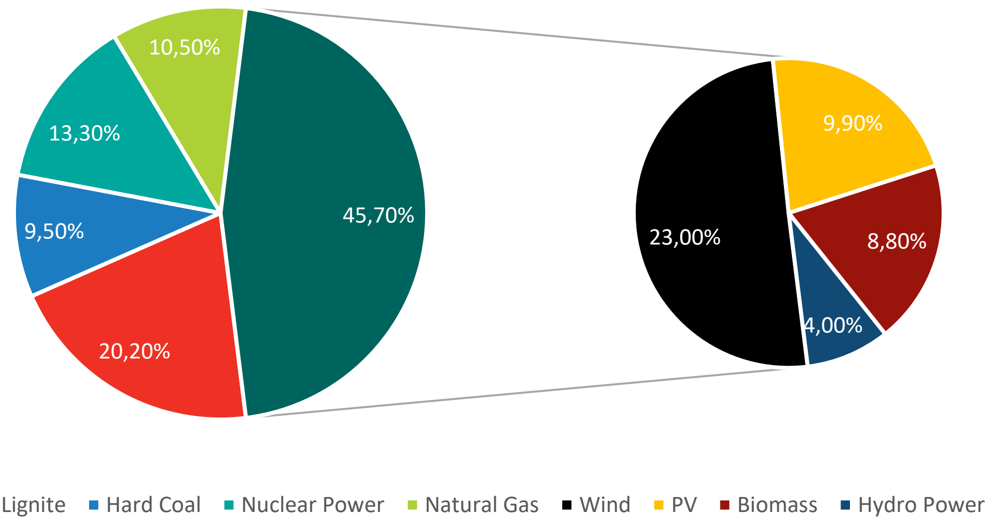


Figure 2-11: Components of German electricity generation in 2021[64]

Coal-fired power generation is 'preferably' phased-out by 2038, and 'ideally' phased-out by 2030. However, given the domestic supply of brown coal (or lignite) and increasing prices of energy stock imports, such as natural gas and oil, these targets are assumed to be soft. Similarly, the phase-out of nuclear energy has been halted, and is expected to temporarily remain in service. Therefore, coal and nuclear are expected to cover for gas fired electricity production in the short term.

While gas fired power only constitutes 10% of the electricity mix, gas import price hikes have already seen electricity prices rise considerably – dramatically effecting the bottom line of businesses, particularly in the industrial sector. The retail price for industrial scale electricity (2,000 MWh to 20,000 MWh) has increased approximately 60% since pre-pandemic levels (12.2 euro cents per kWh in 2018 to 19.5 euro cents per kWh in 2022). In the same period, household prices have increased by around 10% (29.87 euro cents per kWh 2018 to 32.79 euro cents 2022). This price increase has seen windfall benefits for other producers who don't rely on gas, such as brown coal and wind power producers, whose operational costs have risen less dramatically.

[64] Strom-Report (2022). Der Strommix in Deutschland 2021. https://strom-report.de/strom/

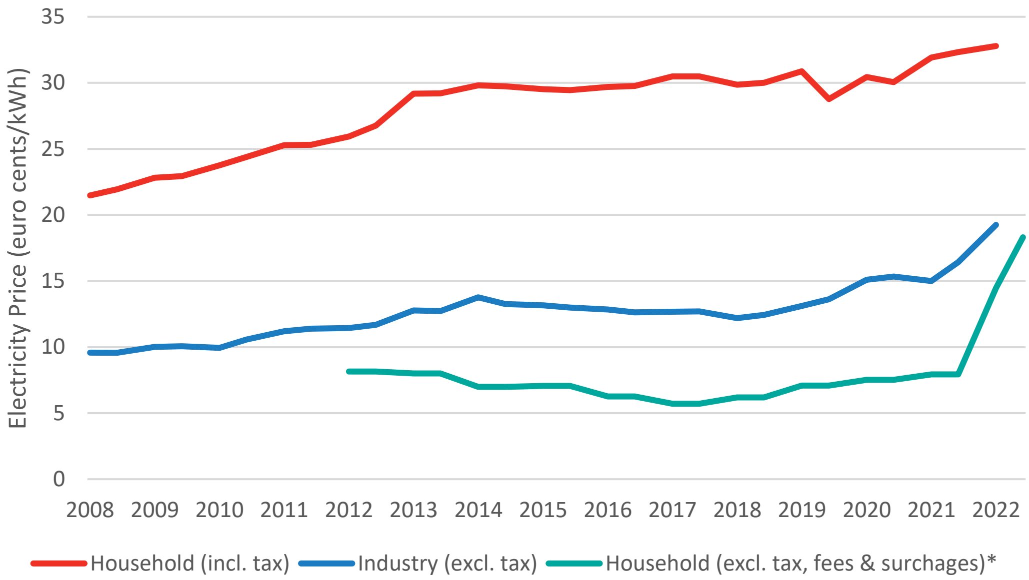


Figure 2-12: German consumer electricity prices[65]
**only price of procurement/distribution[66]*

In 2018, major household electricity price components included the grid fee (24.7%), Renewable Energy Sources Act (EEG) surcharge (23%), procurement and distribution (21%), and Value Added Tax (VAT) (19%). However, the Russian-Ukraine conflict has seen prices for procurement and distribution increase dramatically (+120% from 2021), forcing action by the Federal Government to reduce consumer prices. Since July 1st 2022, the EEG surcharge has been reduced to zero, with the Energy Financing Act completely abolishing the EEG surcharge from 1st January 2023 – effectively leveling out household electricity prices[67]. The EEG surcharge was intended to finance expansion of renewable electricity production, and its abolishment means the federal government will have to pick up the tab through its Climate and Transformation Fund. Price caps have been announced from January 2023 until April 2024, however, the details are yet to be officially published.

On the electricity exchange, the exchange prices result from the interface of supply and demand. The market clearing price is the last offer to be accepted. The power plant with the most expensive marginal costs - the marginal power plant - defines the exchange price for all power plants used. The energy industry refers to this pricing mechanism as "uniform pricing", as all power plants are paid the same price for their feed-in, even if they have offered different prices. This model is called "merit order". Within the merit order, permanently falling electricity production costs shift the conventional order of power plants. Such an effect can currently be observed due to the growing feed-in of renewable energies. Fluctuating feed-in photovoltaic and wind power plants with marginal costs close to zero are advancing into the market and pushing peak load power plants far back in the merit order. Only the residual load - the remaining electricity demand that renewables cannot cover - still must be balanced by conventional power plants[68].

[65] Daten zur Energiepreisentwicklung - Lange Reihe (destatis.de)
[66] BDEW electricity price analysis July 2022 | BDEW
[67] Federal Network Agency - Press - Surplus from the EEG support system in 2023 (bundesnetzagentur.de)
[68] Next Kraftwerke (n.d.): Was bedeutet Merit-Order. Das Merit-Order-Modell: Eine Theorie mit Fragezeichen (next-kraftwerke.de)

The last power plants to receive a surcharge in the merit order are mostly gas-fired power plants, which are decisive for the formation of electricity prices[69]. Due to the strong increase in gas prices, the generation costs of gas-fired power plants have multiplied. In addition to the increased prices, the merit order also shows a steeper curve because it is significantly shorter than the merit order of 2018, i.e. fewer installed capacities are available on the market. While just under 90,000 MW of installed capacity was still available on the market here in 2018, around 65,000 MW is still active on the market this year due to the decommissioning of several power plants carried out as part of the nuclear and coal phase-out and their transfer to the grid reserve. Assuming the average residual load of the months June to August of 2018, the current merit order results in an electricity price of about €350/MWh, ten times as high as in 2018[70].

2.3.4 Gas

The Russian-Ukraine conflict has thrown European energy markets into chaos, with European countries struggling to reduce or substitute Russian gas imports. Germany's heavy reliance on gas and oil for transport and space/process heating means it is especially vulnerable to market price fluctuations. Import prices have exploded higher, with market sources approximating the average household cost of natural gas at 15.29 euro cents / kWh in September 2022, up 150% from 201871. Due to the yearly schedule of residential heating payments from tenants to landlords (known as Heizkostenabrechnung), the price shock is yet to affect many households. However, the closure of gas dependent industry for the winter is a leading indicator of the troubling economic circumstances

[69] Hampp, Melina (2022): Warum steigt der Strompreis, wenn der Gaspreis steigt?. MAXENERGY | Warum steigt der Strompreis, wenn der Gaspreis steigt?
[70] FfE (2022): Veränderung der Merit Order und deren Auswirkungen auf den Strompreis. Veränderungen der Merit Order und deren Auswirkungen auf den Strompreis - FfE München
[71] BDEW-Gaspreisanalyse September 2022 | BDEW

facing Germany soon (industrial gas prices risen by approx. 100% since 2018). Price caps have been announced starting January 2023 until April 2024, however, the details are not officially published.

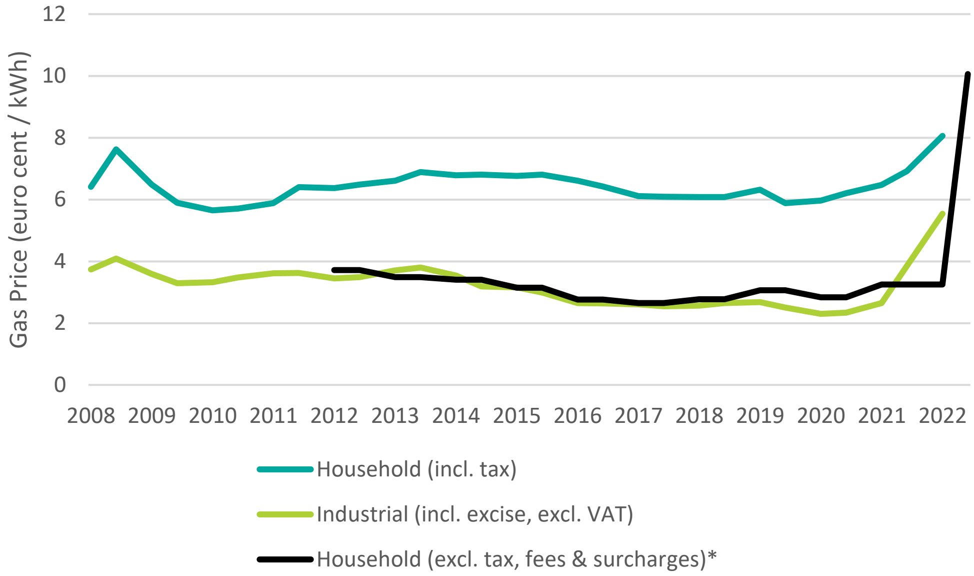


Figure 2-13: German consumer gas prices[65]
**only price of procurement/distribution*[71]

The LNG Acceleration Act creates exemptions for environmental impact assessments and streamlines tender and review procedures to hasten approval and construction of liquified natural gas (LNG) infrastructure. The federal government aims to swiftly expand terminals and Floating Storage and Regasification Units (FSRUs) along its North Sea (Brunsbüttel, Wilhelmshaven, Stade/Bützflet and Hamburg/Moorburg) and Baltic Sea (Rostock/Hafen and Lubmin Through) coastline[72]. Three large suppliers (Uniper, RWE and EnBW) have gained supply rights through a Memorandum of Understanding signed in August 2022[73]. In accordance with German climate targets, the approvals for the LNG facilities are to be limited in duration to no later than 31 December 2043, only continuing operation if they are transformed to handle climate-neutral hydrogen. Prices are expected to remain higher due to greater costs of operation involved in LNG.

The large burden of gas prices on productive industry has reigniting the debate surrounding the domestic exploitation of alternative gas sources (e.g., hydraulic fracking of shale gas). However, the German Federal Government has, so far, remained firm on its 2017 stance – permitting only exploratory boreholes for scientific purposes[74]. The Bundesanstalt für Geowissenschaften (2016), or "Federal Institute for Geosciences", has estimated that German production potential for shale gas is 380 to 2340 billion cubic meters [75] – approximately 2 to 16 years of 2021 consumption. The exploitation of these reserves could see a return to cheaper prices, bolstering domestic supplies like the United States of America. Considering the Federal Climate Protection Act, strong environmental

[72] LNG: securing national energy supplies | Federal Government (bundesregierung.de)
[73] BMWK - Security of supply for LNG terminals
[74] No fracking in Germany (bundesregierung.de)
[75] BGR - Energierohstoffe - Schieferöl und Schiefergas in Deutschland - Potenziale und Umweltaspekte (2016) (bund.de)

protection laws and public resistance - the hurdles of shale gas exploitation are expected to be too great to overcome.

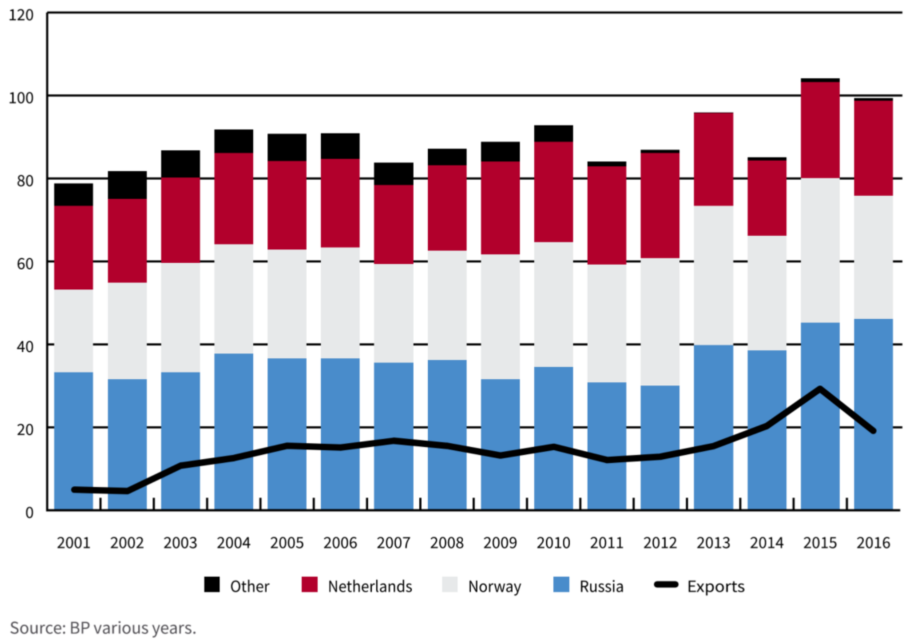


Figure 2-14: Historic German Gas Suppliers (in billion cubic meters) [76]

2.3.5 Heating Oil

Volatile energy markets have also impacted the price of heating oil (or light fuel oil), causing large fluctuations in prices for the consumer. While oil boiler use is small in the German building sector, light fuel oil is used extensively in the industrial and transport sectors and is expected to increase the expense of goods production and transport. Importantly, energy intensive, dense, and high-volume commodities in the construction industry (e.g., steel and concrete) are expected to show lagging effects of price volatility in light fuel oil markets. Like all other energy carriers, the price of light fuel oil has risen dramatically since the Russian-Ukraine conflict, doubling since 2018. Instead of increasing supply to reduce prices, the biggest oil exporting cartel, OPEC+, has decreased supply to maximize profits[77] and prepare for an expected global economic downturn in demand. The outlook remains uncertain, with major recessions in Europe predicted to decrease demand in the future – stabilizing prices.

[76] (PDF) Australia and Germany: A new strategic energy partnership (researchgate.net)
[77] US-Saudi rift grows over decision to cut oil production | Saudi Arabia | The Guardian

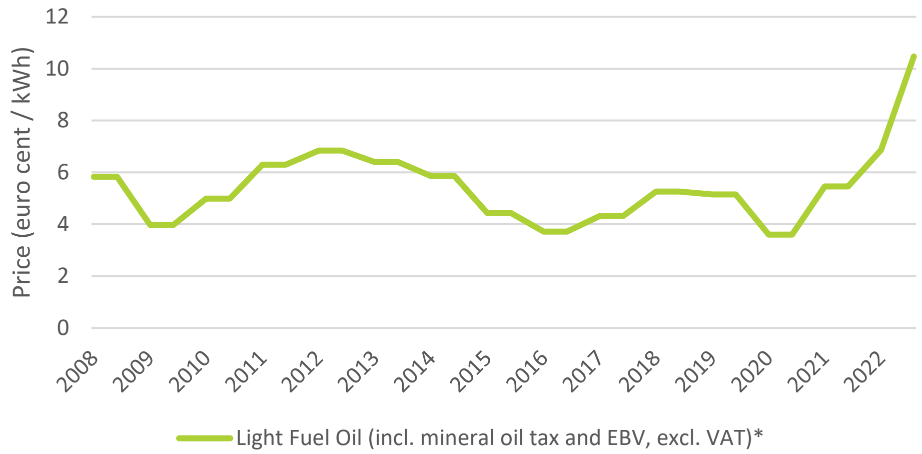


Figure 2-15: German light fuel oil prices[65]
** calculated using 1 liter = 11kWh*

2.3.6 District Heating

District Heating Systems (DHSs) promise a low CO2 to CO2-free heat supply through their ability to use spatially distributed renewable energy sources efficiently. Typically, they improve the efficiency of combustion processes used for electricity production (in combined heat power operations) by salvaging high temperature waste heat for reuse. However, high temperature steam networks require different exchangers compared with lower temperature networks, with sub-systems dependencies occurring due to the disparate operating conditions. Care must be taken when expanding district heating to ensure networks do not rely on the high thermal qualities only possible with combustion processes – instead pursuing low temperature networks. Cohesive organization of district heating networks toward a common standard and goal is required by the government, which begins with open access to information via a Market Transparency Act (like the electricity network).

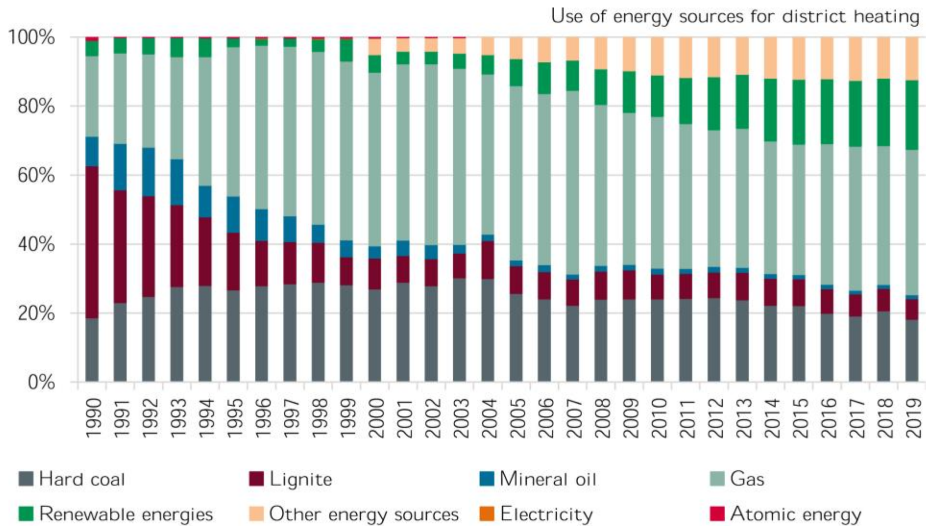


Figure 2-16: Share of the main energy sources supplying district heat[78]
**other energy sources include incineration of non-renewable waste and waste heat*

[78] District heating atlas - Analysis of the German district heating sector - ScienceDirect

While district heating systems (DHSs) only constitutes 14% of household heating, the subsidization by federal funding is expected to broaden its reach via the Building Energy Act (GEG), Federal Funding for Efficient Buildings (BEG), the Federal Funding for Efficient Heating Networks (BEW) and the Federal Climate Protection Act (KSG). The GEG considers that the use of more than 50 percent of energy from gas-fired combined heat and power (CHP) as 'renewable energy' – providing subsidies for connections under the BEG funding program. The BEW is intended to act as a supplier counterpart to BEG, also subsidizing the operation and expansion of heating networks given a 'transformation plan' toward climate neutral operation. Finally, the Federal Climate Protection Act indirectly incentivizes the use of district heating through its carbon pricing scheme, which exempts carbon fees for customers of fossil-fuel fired district heating.

The variety of district heat sources, operating temperatures, and companies as well as the lack of legislation requiring transparency of quantitative data results in few data sources. The Efficiency Association for Heating, Cooling and CHP (AGFW) offers reports on an annual basis, with the last report published in December of 2021. Therefore, the impact of the Russian-Ukraine conflict is yet to be published, with only price indices available from the Federal Office for Statistics (DeSTATIS) spanning until September 2022. According to AGFW, the average price of district heat has increased from 7.67 euro cents / kWh (in 2018) to 8.28 euro cents / kWh (in 2021). However, price indices show a dramatic increase of roughly 30% from 2021 to 2022. Therefore, prices in 2022 may be estimated at 10.76 euro cents / kWh or 107 euro per MWh.

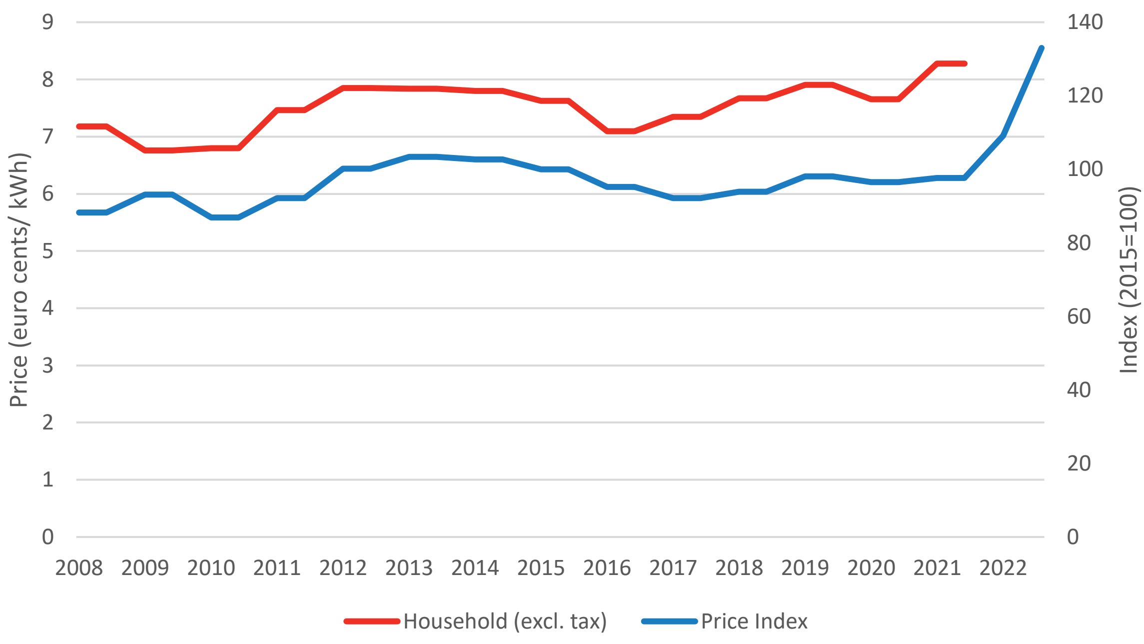


Figure 2-17: German consumer domestic heating price and price index[65]

2.3.7 Conclusions

The German building sector represents roughly 35 percent of national energy consumption, with space heating constituting the largest fraction. Comparing the residential and commercial building sectors, existing residential buildings have the highest space heating demand and highest impact in terms of potential energy reductions. The Federal Climate Protection Act (KSG), and it's 2021 amendment, legally bound Germany to achieve targets of carbon-neutrality by 2045, pushing stringent updates to the Building Energy Act (GEG) and providing additional funding via the Federal Support for Efficient Buildings (BEG). Funding for individual measures (BEG EM) is typically used for renovation of existing buildings and heavily emphasizes converting systems to:

- **Solar thermal**: low thermal quality (flat panel, domestic)
- **Heat-pumps**: low thermal quality (air source, domestic)
- **Renewable hybrid systems**: high thermal quality (with biomass)
- **Connection to a heating network:** high thermal quality (low temperature networks possible but rare)

The market has responded to these incentives strongly, with biomass and heat pumps, particularly in new builds, increasing in market share substantially. However, the funding strategy is somewhat short sighted – most existing systems required high thermal quality (i.e., high supply temperatures). Changing from high to low thermal quality energy sources is far more difficult (and expensive) than simply swapping an old oil boiler (banned by 2026) for a biomass boiler. Low thermal quality systems (also known as low temperature systems) require increased pumping volumes and emission areas with decreased peak loads. This typically translates into larger pipe diameters (increased flow rates) and heated areas (e.g., underfloor), with better building envelope (peak load reduction). Instead, the BEG EM gives only a small percentage to the typically much greater costs of building envelope improvements, which would potentially both reduce consumption in the short term and allow low temperature system integration in the medium-to-long term.

Barriers for renewable investments were found predominantly in the existing residential sector, involving 'split incentives' between tenant and landlords. The bulk of urban residential buildings in Germany are rented, with renter occupier rates as high as 85% in Berlin. Property owners can pass operational costs onto tenants, limiting their exposure to energy price increases. Further, small scale property owners feature limited resources to navigate complex energy efficiency upgrade applications and seek easier rental returns offered by cosmetic renovations. Therefore, the financial incentives (carrots) or standards enforcement (sticks) must be strong to force action if targeted towards landlords. Conversely, enabling and supporting the group which promises to gain from reduced energy consumption – owner occupiers and tenants – might be a far more cost-effective route.

The federal government has also incentivized increasing the generative capacity and extent of district heating and community electricity networks via the Federal Funding for Efficient Heating Networks (BEW) and German Renewable Energy Sources Act (EEG). Buildings' use of district heating with more than 25% renewable energy or primary energy factor not exceeding 0.6 satisfies the 'use of renewable energy' criteria in the GEG. Incinerated waste which contains more than 50% biodegradable fraction is considered a renewable energy source in Germany, while gas and LNG fired combined-heat-and-power (CHP) operations satisfy the primary energy factor of ≤ 0.6. Under the BEW, district heating networks are eligible for significant planning, construction, and operation subsidies (~40%) given a 'transformation plan' to carbon-neutral operation by 2045. For electrical networks, updates to the EEG have scrapped the metering and remuneration of self-consumption (in practice complex to enforce), in favor of higher feed-in tariffs of up to 13 euro cent / kWh. Further, the sale of electricity directly from landlord-to-tenant is subsidized via the *Mieterstrom* program, featuring no taxes on electricity sold within small, private networks.

These programs are good first steps on paper to achieving carbon reductions, however, their practical implementation faces some barriers. While district heating systems promise a low carbon to carbon-neutral heat supply through efficient sharing of distributed renewable energy sources - they must feature low operating temperature. Most district heating systems feature high operating temperatures, with all dependent subsystems designed for those conditions. While faster in the short term, the use of high temperature district heating networks will inevitably lead to much larger costs to switch to low temperature distribution in the future or will use scarce carbon-neutral combustion sources (biomass/biogas/hydrogen).

While the reforms to the EEG are in the right direction, some negative side effects of high feed-in tariffs are expected. High feed-in tariffs incentivize the installation of photovoltaic without storage, limiting the value of self-consumption. The production of hydrogen via electrolysis is promoted as a measure to store oversupply, particularly during summer. However, the speed at which hydrogen production can scale to counterbalance PV oversupply is up for debate. Another issue arises with ownership and liability of building integrated photovoltaics (BIPV) for 'landlord-to-tenant' supplied electricity. As a part of the building envelope, landlords cannot simply rent out space for BIPV operators and must assume the liability of being an energy provider. Regardless, the issues for PV are minor and the outlook good, especially given the high electricity prices.

Energy markets and prices are responsible for the bulk of operational overheads in building space and process heating. For this reason, the Federal Climate Protection Program (KSP) introduced a carbon fee of 25 euro per ton of CO2 equivalent emissions (or roughly 0.5 euro cent per kWh for natural gas) for the transport and heating sectors – aiming to increase it to 55 euro per ton by 2025. However, the price volatility promoted by the Russian-Ukraine conflict dwarfs this policy, in some cases doubling prices (roughly +2.25 euro cent per kWh for industry). In response, the federal government has cut value added taxes (VAT) from 19% to 7% on gas until 2024. Prices are expected to remain high due to liquified natural gas being inherently more expensive than piped natural gas. In a draft resolution, the federal government also aims cap electricity and gas prices for consumers, expected to come into effect in January 2023 until April 2024.

Due to the lack of cheap gas supply, the massive investment in condensing gas boilers and CHPs over than past decade will be a headache for many years to come. Yet legislation, such as the GEG, continues to advocate their use. Germany must reserve the use of renewable combustion sources for industrial processes rather than space heating or electricity generation – where other alternatives exist. Switching to low temperature heating systems features large initial investments but is economical in the long-term, especially given the high energy prices expected. However, as government interest repayments increase due to higher debt and interest rates, grants offered by the government look likely to reduce[79]. The window of opportunity to transition to low temperature space heating systems looks to be closing rapidly.

[79] German Bundestag - Draft Budget 2023 forwarded

Key takeaways

"Changing from high to low thermal quality energy sources is far more difficult (and expensive) than simply swapping an old oil boiler (banned by 2026) for a biomass boiler."

"Property owners can pass operational costs onto tenants, limiting their exposure to energy price increases… Conversely, enabling and supporting the group which promises to gain from reduced energy consumption – owner occupiers and tenants – might be a far more cost-effective route."

"… the issues for PV are minor and the outlook good, especially given the high electricity prices."

"While faster in the short term, the use of high temperature district heating networks will inevitably lead to much larger costs to switch to low temperature distribution in the future or will use scarce carbon-neutral combustion sources (biomass/biogas/hydrogen)."

"The massive investment in condensing gas boilers and CHPs over than past decade will be a headache for many years to come. Yet legislation, such as the GEG, continues to advocate their use. Germany must reserve the use of renewable combustion sources for industrial process heating rather than space heating or electricity generation – where other alternatives exist."

3 Appendix C: Greece

3.1 Cultural, economic, and social aspects

Lobbying against RES has been highly successful; thus, it is not easy to change the way people think about renewables, and that awareness raising campaigns have an effect only if they are spread over longer periods of time.

The effects of a RES-based transition on vulnerable consumers should always be considered since energy poverty is an existing problem and instead of solving it, the energy transition might create new vulnerable groups of consumers, especially after the total shutdown of lignite-fired power plants.

Within a wider social aspect, the implications of the energy transition can span a large landscape. The shutdown of thermal power generation resources will be at the cost of job losses, especially in regions where the economic activity is largely dependent on fossil resources. Finally, an important point that was raised is that even though the energy transition will have a positive overall impact, the designed policies might not be based on citizens' needs.

Lastly, customers don't seem to trust new suppliers or technology, which is discouraging. However, recently there is a large shift towards heat pumps for both heating and cooling, not only for new buildings but also for renovations.

In the current building stock, not surprisingly, newbuilt homes and retrofits have an energy class of A-B by 94.21%.

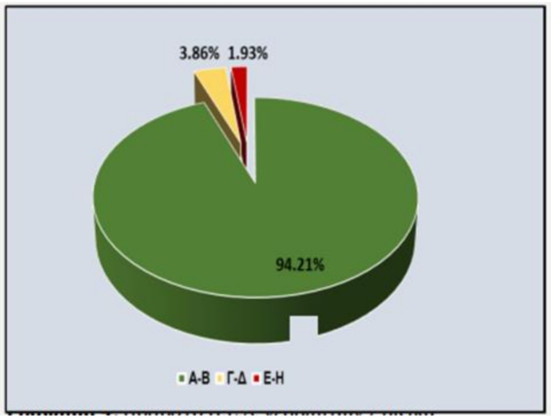


Figure 3-1: Percentage of newbuilt/retrofits buildings by energy class, 2020

3.1.1 Residential

According to the most recent statistical data from the Ministry of Environment and Energy, single-family houses are the most energy consuming from residential buildings having an annual average primary energy consumption 437.81 kWh/m^2 where for apartments and flats annual average primary energy consumption is 311.84 kWh/m^2 and 267.3 kWh/m^2 respectively. In residential buildings the higher energy percentage is consumed for heating with an annual average primary energy consumption of 336.89 and 178.63 kWh/m^2 respectively, while cooling and hot water consumption are comparable and in the range of 33-55 kWh/m^2. The majority of cooling appliances are electrically driven such as split air-conditioning units.

The picture below is taken from the report, and it shows that the biggest percentage of residential buildings have an energy class of E-H, 21.59% of C-D and a very small percentage has an energy class of A-B.

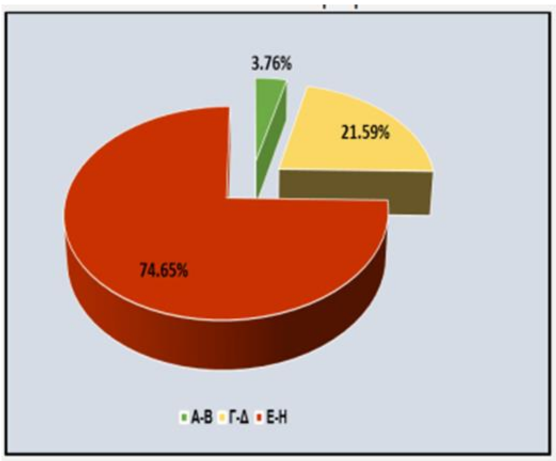


Figure 3-2: Residential buildings EPC percentage per energy class, 2020

Energy cost represented around 10% of the total household expenditures in 2019, as shown below. Among EU countries, Greece has experienced the biggest increase concerning the inability to keep homes adequately warm, though this trend seems to decline.

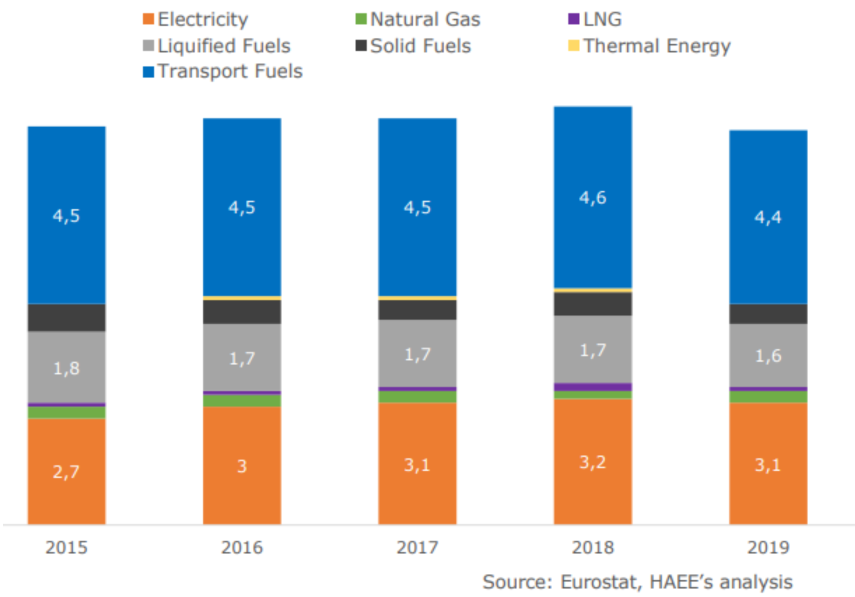


Figure 3-3: Household expenditure for Energy Products as Share of Total Household Expenditure (%), 2015-2019. (Source: https://www.haee.gr/FileServer?file=0d05aabb-92c0-4a66-89d2-827aaab2ef65)

The new “Exoikonomo-Aftonomo” programme, deriving from the EU Recovery Fund, a mechanism to mitigate COVID-19 effects, could facilitate the sustainability of household refurbishments in the residential sector (Hellenic Ministry of Environment and Energy, 2020).

The 'Energy Savings in Households (Eksikonomisi kat’ Oikon)' programme, was launched by the former Ministry of the Environment, Energy and Climate Change (YPEKA), to promote energy retrofitting of existing buildings. This programme offered a set of financial incentives for household owners to implement energy efficient technologies that focus on the building envelope, the heating and cooling systems, and DHW systems. As successful as it was, in 2018 the second cycle of the programme was launched[80].

3.1.2 Offices

According to Annual report of statical analysis for 2020, 21.12% of the total buildings audited for the year 2020 concerns tertiary sector buildings, where 57.61% are shops (28,949), 20.19% are offices (10,147), and cover a total area of 8,476,709.56 m2.

Regarding the energy category of buildings tertiary sector, it is observed that the largest percentage of them (53.35%) is classified in energy category E-H, 42.81% in C-D and just 3.84% in A-B.

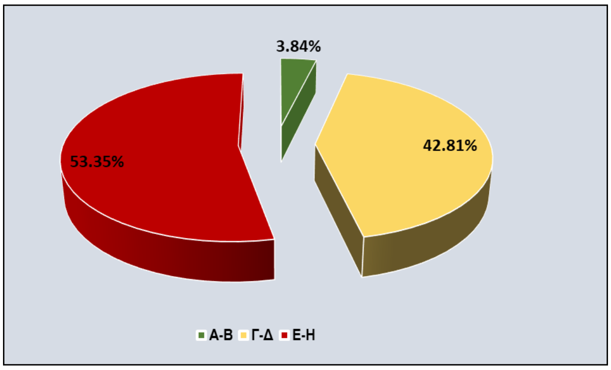


Figure 3-4: Percentage of tertiary buildings by energy class

The specific primary energy demand in office buildings follows a different pattern as in residential ones. Less heating and DHW is needed, while the cooling demand is comparable to the heating and lighting of about 120 kWh/m^2 each. The similar trend also applies in all tertiary buildings in Greece, with the highest primary energy for cooling and lighting in hotels and sporting centers, with an average primary energy demand over the whole sector of about 160 kWh/m^2 (Annual Statistical Analysis of 2020). Also, it is found that electricity contributes an average of 81.05% to the energy balance of tertiary sector buildings, while oil by 16.54% respectively.

The majority of the buildings of this sector are of the lowest energy class, while only a very small share belongs to the energy class of A-B, with offices following the same trend.

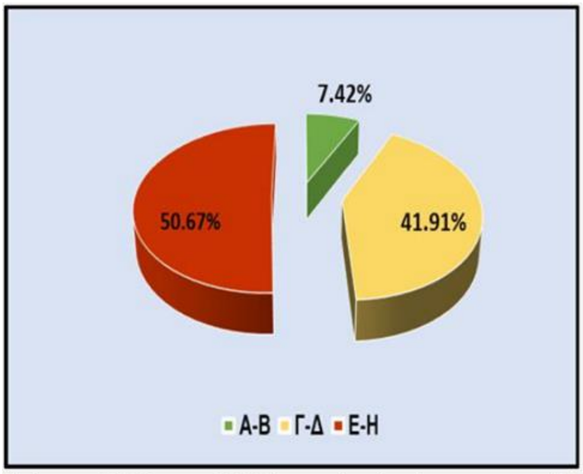
3.1.3 Public

In 2020, only 0.37% of published energy certificates belong to public sector. The most energy-intensive public service buildings for the year 2020 are indoor swimming pools (average annual consumption of primary energy 1,585.38 kWh/m^2), the indoor gyms (average annual primary consumption energy equal to 1,233.15 kWh/m^2) and institutions (average annual primary energy consumption equal with 879.43 kWh/m^2).

In public service buildings, the largest percentage of energy is consumed for the coverage of heating needs (average annual consumption of primary energy in heating equal to 149.70 kWh/m^2) and in lighting (average annual consumption of primary energy in lighting equal to 104.37 kWh/m^2). However, in some types of public buildings, such as sport centers or hospitals, cooling demand is also significant.

[80] https://sentinel.energy/wp-content/uploads/2021/04/Greek-CS_-Synthesis-Report.pdf

Below, the picture shows that there is almost half and half distribution between the public sector buildings between energy class C-D and E-F, with the highest classes barely noted with 7.42% of public sector buildings.



Γράφημα 29. Ποσοστό Π.Ε.Α. κτηρίων δημόσιων υπηρεσιών ανά ενεργειακή κατηγορία (2020)

Figure 3-5: Percentage of public service buildings by energy class

3.2 Building codes and regulations

New buildings or building units must meet minimum energy performance requirements (classB) set out in the KENAK regulation.

In July 2017, the KENAK was amended according to the results of a cost-optimal study. This study determined the minimum energy performance requirements for new buildings or building units and for existing ones that undergo a major renovation, so that the maximum energy savings are achieved with a lower cost impact.

Moreover, every new building of the public sector from 1 January 2019 should be NZEB. This obligation also applies for all new buildings constructed after 1 January 2021. The definition of NZEB has been used since 2013. The national plan for increasing the number of nearly zero-energy buildings was issued in August 2018 and defined, among others, that a new building may be characterised as a nearly zero-energy building if it falls at least under energy class A, while an existing building when it falls at least under energy class B+[81].

Nevertheless, a decision on the minimum share of RES and the way it contributes to primary energy consumption is still pending. The YPEN is expected to procure a study in the first semester of 2020 to deal with these issues.

At the stage of issuing a building permit for new buildings or building units, additional documentation must be prepared and submitted to the relevant Building Office Authority. This documentation accompanies the energy study and contains the technical, environmental, and economic feasibility of the installation of at least one of the following alternative energy supply systems:

[81] https://epbd-ca.eu/wp-content/uploads/2022/02/Implementation-of-the-EPBD-in-Greece-2020.pdf

- decentralised energy supply systems based on RES
- combined heat power (CHP)
- district heating or cooling systems in the region or block
- heat pumps that meet the minimum eco-labelling requirements

For new buildings or building units, it is obligatory since 2011 to cover part of the hot water needs from solar, thermal or other RES/CHP systems. The minimum percentage of the solar share on an annual basis is set at 60%. Non-application of the above rate requires adequate technical documentation in accordance with current legislation and the prevailing conditions.

The existing legal framework for small-scale PV systems is rather complicated and does not contribute to the wider penetration of the technology. On the other hand, most of the stakeholders agreed that for small-scale, decentralised RES projects, and particularly PV, self-consumption models could emerge, in which prosumers would consume most of the electricity generated at the local level and sell the excess to the grid. This is supported by the net-metering option of small PV systems that currently exists and has attracted the interest of many homeowners (commonly, feed-in-tariffs scheme applies to older prosumers in the mainland and net-metering to newer ones). The high available solar radiation in most of the locations of Greece contribute to the large amounts of PV electricity production, which greatly reduce the electricity needed from the grid and resulting to relatively short payback periods. A funding scheme is expected in 2023 that will provide subsidies (around 50% of installation costs) for installing rooftop PVs under the net-metering option.

The main challenge of decentralised generation and prosuming is that initial costs of RES technologies may be prohibitive for investments, despite the benefits over the technologies' lifetime. This fact is even more obvious in the case of economically vulnerable consumers. As a stakeholder pointed out "if leasing models are offered to consumers by electricity providers, who will own the central storage systems and act as aggregators, then, in this case, the prosumer model would not be attractive." To overcome this, net-metering started to be applied even in energy communities with the relevant legislation put into force in 2016, in which a number of individuals or even legal entities could collectively form a small/medium producer and benefit from the electricity balancing option. In this case, virtual net-metering applies, because the PV system is usually far away from the consumers' premises, but still in the same region.

Finally, novel regulatory frameworks, to ensure that the post-lignite development trajectory in the coal regions is socially just, are required. The latter also includes social innovations relevant to the concept of energy citizenship, such as energy communities, ecovillages, and others.

3.2.1 Net metering

Greece introduced policies (ΦΕΚ Β 3971 30 08 2021) boosting the country's net metering and small-scale solar PV sectors. Specifically, the country increased the upper limit for net metering installations in the mainland grid from 1 MW to 3 MW. The policy change concerns consumers in the mainland as well as on the island of Crete, given that Crete linked to the mainland electricity system in May.

Equally significant though was a new measure introduced in autumn to phase out a licensing requirement concerning net metering systems of up to 50 kW. Until recently these systems needed a connection agreement from the country's distribution network, which was often time-consuming. The requirement for such an agreement has now been phased out.

The new net metering policy also allows the installation of net-metered systems in congested parts of the network as long as these systems do not inject electricity into the grid. The timing of a net metering investment is now fully defined, with both the investor and the country's institutions having to comply with specific timelines.

3.2.2 Sub-500 kW solar sector

The policy change concerning ground mounted solar farms up to 500 kW of capacity is also important given this sub-sector added about 1 GW of new installations. Projects under 500 kW were supported by feed-in tariffs (FITs), but starting in 2021, the government required such systems to compete in the nation's renewables tenders. The government reversed part of that decision, however, providing another two years of stable remuneration support to those sub-500 kW investors who do not own more than one solar park supported by FITs. Therefore, investors who only own one sub-500 kW PV farm can still apply for FIT remuneration until the end of 2022.[82]

3.2.3 ELEKTRA program

The 'ELEKTRA' program outlined in Law 4608/2019 is a new program for energy efficiency renovations in public buildings. This program will provide loans to General Government bodies in order to implement energy efficiency investments in their buildings. Loans will be financed or co-financed by the national part of the National Investment Program as well as by beneficiaries' own resources. Recently, an addition to the project's design made it possible to finance part or all of the investment by using Energy Service Companies (ESCOs). The programme is expected to be launched in autumn 2020[83].

3.2.4 SAVE I (Eksikonomo I)

The national programme 'SAVE I (Eksikonomo I)', addressed to municipalities of over 10,000 inhabitants, provides subsidies for implementing energy efficient technologies in buildings owned or used by municipal services. The subsidy provided was up to 70% of the cost of the energy efficiency measures. A total budget of 82 million € was allocated during the first phase of the program (2009 - 2012). The proposed measures included building envelope measures and equipment for efficient heating, lighting, ventilation, cooling and control systems. This first phase proved to be successful and was welcomed by local authorities. The program was therefore extended and is on-going.

3.3 Energy market rules and tariffs

Electricity market is considered as a key sector in Greece, since generation, transportation, distribution, supply, and trade of electricity produce 2% of national Gross Added Value of the total economy. Gross electricity generation in 2019 remained relatively steady compared to 2018 levels, reaching 53,3 TWh. Covid-19 affected the total electricity consumption in Greece, an index which continued to decline for a third consecutive year.

The further decarbonization process of the electricity generation in Greece continues, with the lignite share dropping at 10.3% in October 2020. The share of RES recorded the most significant growth in the electricity mix, increasing by 9.7% during the period December 2019 - October 2020. April 2020

[82] https://www.pv-magazine.com/2021/11/12/greeces-policy-reform-fever-storage-net-metering-and-sub-500-kw-solar/
[83] https://epbd-ca.eu/wp-content/uploads/2022/02/Implementation-of-the-EPBD-in-Greece-2020.pdf

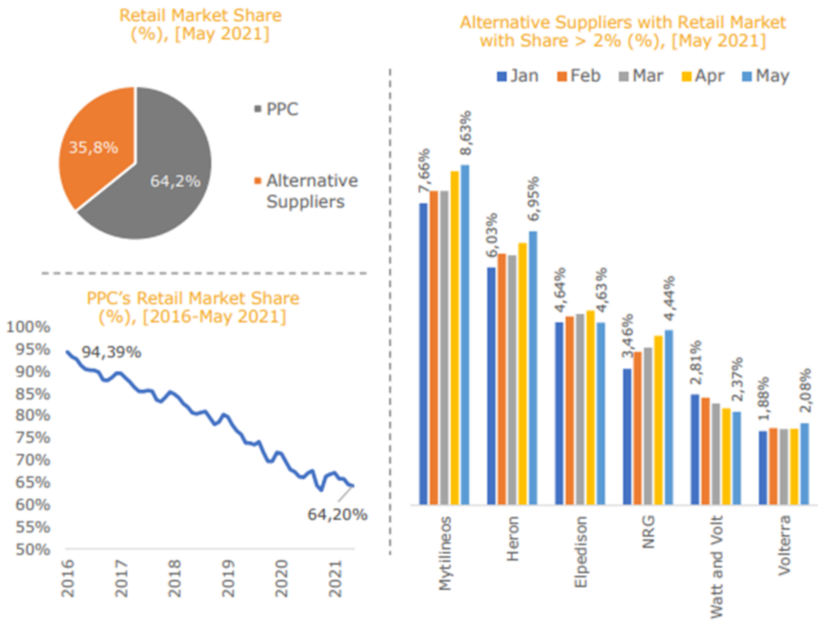
was characterized a “Snapshot from the Future”, when natural gas and RES prevailed in the electricity mix. CO2 emission allowances directly affect electricity prices and contribute to emissions reduction through Europe. Beyond lignite-fired units, natural gas-fired units are also affected by the increasing cost of CO2 emissions, however at a lower magnitude. In 2020, RES and Hydro together represented greater share of total capacity (53%) compared to Coal and Natural Gas combined (47%). The incumbent, Public Power Cooperation (PPC), retained a dominant share in electricity generation. PPC’s share in the retail market continues the downward trend, reaching 64.2% in May 2020 from 94.3% in January 2016.

The Target Model was officially introduced in November 2020, while Derivatives Market is available to market participants since March 2020. A significant drop in wholesale electricity prices occurred during the 1st period of Covid-19 lockdown, reaching 28.5 €/MWh in April 2020. Greece continues to face the 2nd most expensive wholesale electricity price throughout Europe (52.9 €/MWh), for a second year in a row. Due to the Covid-19 effect, 2020 was an unusual year, and seasonality did not affect the variation of electricity prices. Since 2008, the daily average market clearing price in Greece fluctuated from 10 €/MWh the lowest to 123 €/MWh the highest value, with an average price at 54.1 €/MWh. Overall, 22% of electricity prices for non-household consumption in Greece is attributed to taxes, fees, levies and charges.

Finally, the Greek EV market has been rather immature, although from 2019 onwards an increasing trend has been recorded. Total fleet of EVs increased from 62 in August 2014, to 2.131 in August 2020. More specifically, sales rocketed right after the launch of “Kinoume Ilektrika” incentive, reaching 10% of monthly total market share in December 2020. The Greek government announced a variety package of economic incentives, tax reduction, exemptions and funding programs, supporting the promotion and the deployment of electric cars and charging stations. The second round of this scheme is expected in 2023.

3.3.1 Retail Market

PPC’s (Public Power Corporation SA) share in the retail market continues the downward trend, reaching 64.2% in May 2020 from 94.3% in January 2016.



Source: HEnEx, HAEE’s analysis

3.3.2 Electricity Price

Since 2008, the daily average market clearing price in Greece fluctuated from 10 to 123 €/MWh, with an average price at 54.1 €/MWh.

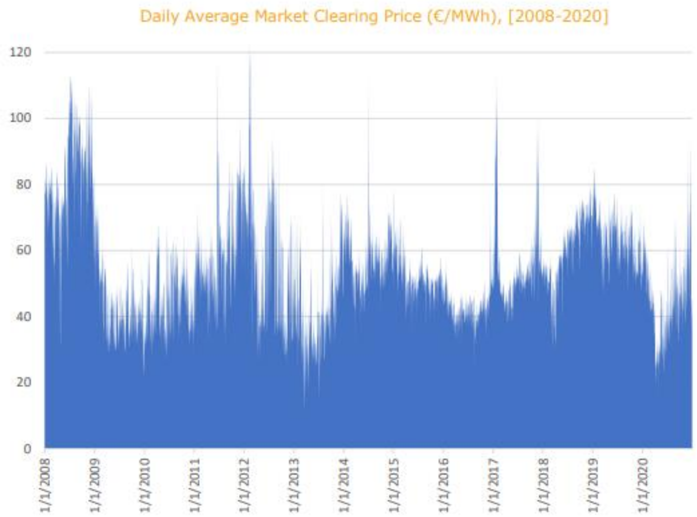
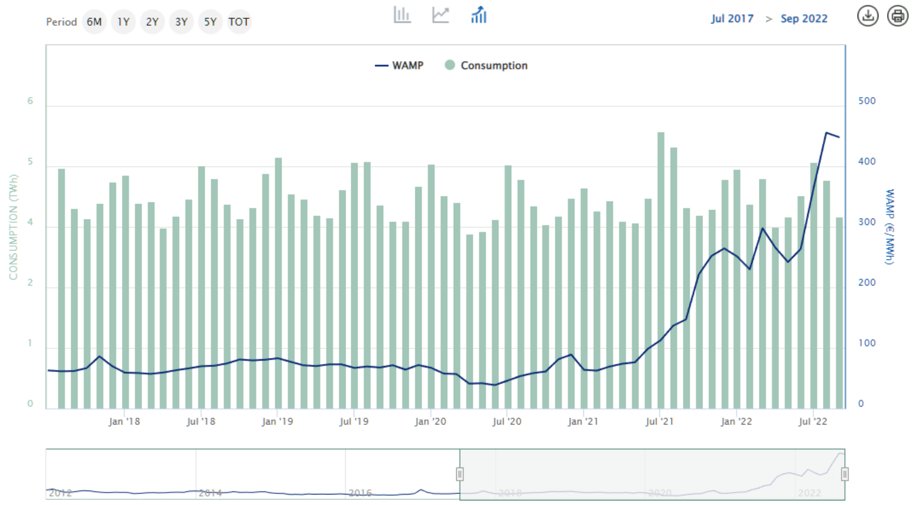


Figure 3-6: Daily Average Market Clearing Price (€/MWh), [2008-2020]



Average Weighted Average Market Prices (€/MWh) per month from 2012 to present											
January	February	March	April	May	June	July	August	September	October	November	December
90,74	84,78	85,57	79,49	78,89	83,61	96,69	106,72	107,59	82,71	89,17	93,13

Figure 3-7: Average Weighted Average Market Prices (€/MWh) [2017-2022] [84]

22% of electricity prices for non-household (industries) consumption in Greece is attributed to taxes, fees, levies and charges and this decreases to only 15.5% for household consumers, still considerable factor.

[84] https://www.admie.gr/en/agora/statistika-agoras/kyrioi-deiktes-dashboard/mesostathmiki-timi-agoras

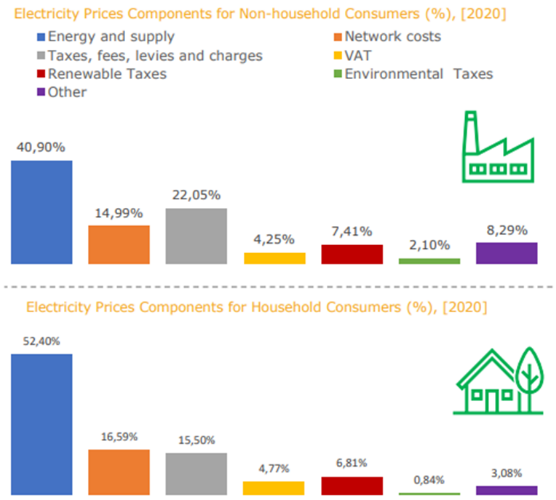


Figure 3-8: Electricity prices components for non-household and household consumers (%), [2020]

3.3.3 Energy mix

In 2018, oil remained the dominant energy source of final consumers (52.9%), due to 'oil-based' transport, while renewable energies covered 10.6% of final energy consumption[85] [86].

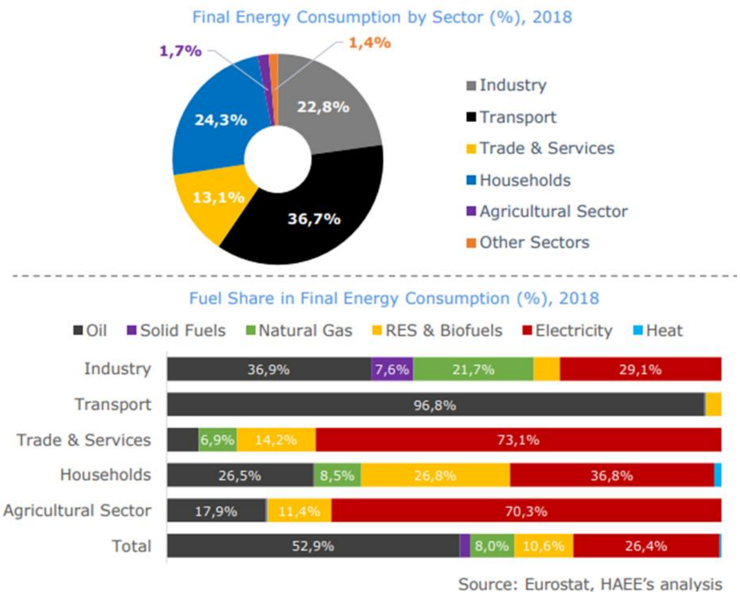


Figure 3-9: Final Energy Consumption by Sector (%), 2018

The electricity energy balance in 2020 was formed at 29% (14.773 GWh) RES, 36% (17.808 GWh) natural gas, 11% (5.722 GWh) lignite, 6% (2.899 GWh) hydro and 18% imports (8.861 GWh)[87].

85 https://www.haee.gr/publications/haee-publications/greek-energy-market-report-2021/#mm-10
86 https://www.haee.gr/FileServer?file=0d05aabb-92c0-4a66-89d2-827aaab2ef65
87 https://www.rae.gr/statistika

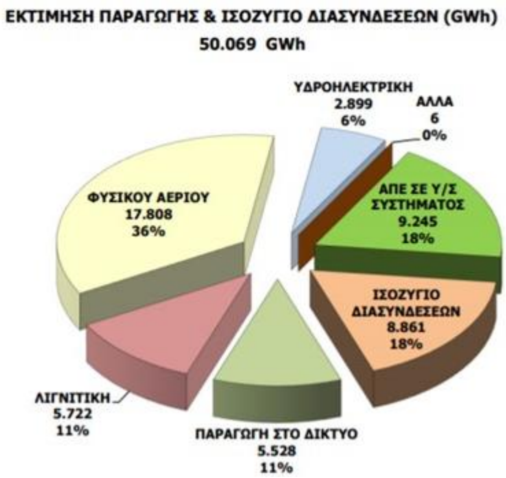


Figure 3-10: Electricity Energy Balance, 2020

The turning point for energy transition in Greece occurred during the first quarter of 2021, where renewables and hydro share overpassed fossil fuels share for the first time in Greece.

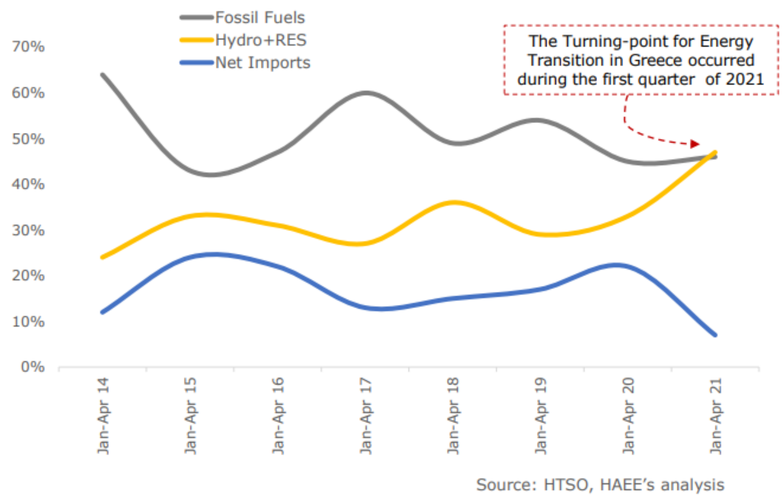


Figure 3-11: Electricity Generation Share in the Interconnected System (%), [2014 – Q1 2021]

3.3.4 National Policy

In Greece, the main directions of EU policy have been incorporated into the National Energy and Climate Plan (NECP), which published in December 2019 and is the core tool energy policy of the country to achieve qualitative and quantitative goals in the period 2021-2030. The ESEK specifically includes policy measures, which take into account potential, techniques peculiarities and the quality characteristics of the Greek energy sector system in the areas of production, distribution and consumption energy. It specifically provides for:

- Reduction of greenhouse gas emissions by more than 42% compared to emissions in 1990 and more than 56% compared to emissions in 2005
- Increase the share of RES to at least 35% of final energy consumption by 2030 and the RES share in electricity consumption to exceed 60%.
- Improvement of Energy Efficiency (EA) by at least 38% by 2030 compared to projections made in 2007.

- Zero share of lignite in electricity generation by 2028.[88]

The NECP includes and sets out corresponding measures for other strategic policy priorities such as:

- speeding up the electrical interconnection of the islands;
- launching the new electricity market model without further delay;
- strengthening energy interconnections;
- developing strategic storage projects;
- digitizing the energy networks;
- promoting electromobility;
- promoting new technologies;
- coupling the final sectors;
- developing new financial instruments; and
- taking initiatives for research and innovation and for enhancing competitiveness.[89]

3.3.5 Policies

Greece is currently undergoing major energy sector reforms, aiming to transform the operation of the energy system, foster competitive energy markets, create significant investment opportunities, reduce greenhouse gas emissions, tackle existing climate change effects, and ultimately facilitate a green energy transition.

The development of the national energy and climate plan for 2030, combined with Greece's energy privatisation plan and the impressive increase in renewable energy sources (RES) potential in its power production, is indicative of Greece's strong position as an important participant in the European energy mix. An important aspect of upcoming energy reforms is directed towards electrification and cost reduction driven by technologies such as smart grids, e-mobility and energy-efficient buildings. Major infrastructure development initiatives, such as interconnecting the Greek islands with the mainland grid system, and the establishment of the Hellenic Energy Exchange (HEnEx), are some of the landmarks of the transition into the new era that is under way in Greece's energy landscape.

Greece auctions awarding feed-in premiums

In 2016, Greece adopted a Development Law. The Law supports the deployment of renewable technologies along with auctions awarding feed-in premiums from 2017.The Law introduces an income tax relief and stabilization of income tax coefficient to renewable and CHP plants through tenders. Auctions are technology-specific and the Ministry of Environment and Energy issues decision specifying capacities to be auctioned for each eligible technology.

Selling electricity back to the grid for building owners has been technically feasible but difficult to implement due to licensing requirements. In June 2022, Greece's Ministry of Environment and Energy put through a new law in parliament that covers licensing of renewables and other measures related to the energy crisis. According to the law, the number of licensing stages is reduced from 7 to 5, and the process of amending licenses is also simplified. There is also a significant change concerning the distribution grid and its operator, HEDNO. From now on, the company will calculate available electric

[88] https://www.dianeosis.org/wp-content/uploads/2021/07/Energy-VERSION-30.06.2021.pdf
[89] https://energy.ec.europa.eu/system/files/2020-03/el_final_necp_main_en_0.pdf

space in its various local substations. Wherever a margin is identified, it will be provided for self-consumption or net metering plants of up to 10 kW.

New margins are 30% for households, 30% for farmers, 30% for industry and 10% for independent producers. The ministry believes that 200,000 small PV systems would be constructed with the new measure and that it would translate to 2 GW of renewable electricity capacity.

4 Appendix D: Ireland

4.1 Cultural, economic, and social aspects

Cultural and societal norms can prove to be effective parameters that provide insight into the energy consumption habits of a population. Understanding such norms can inform design interventions which enable behavioural change conducive to sustainable use of energy by encouraging responsible consumption habits. The benefit of a behavioural shift within society can potentially initiate a butterfly effect leading to greater energy savings among the population, an increased use of sustainable energy sources and a shift towards low carbon behaviours such as cycling and use of public transport. The ripples of such a shift consequently influence the economic and social policy to take more sustainable directions. With current climate change issues and Ireland's vulnerability to intense weather shifts and coastal flooding, it is crucial that as a nation, Ireland shift towards more sustainable energy consumption patterns.

4.1.1 Residential

Ireland faces a number of barriers regarding culture and economics which limits the adoption of a low carbon energy infrastructure. Domestically, the capital expenditure cost for transitioning to low carbon technology is significantly high. Similarly, in the commercial sector, the cost of replacing existing energy systems with low carbon energy sources is also very steep. At present, there is an existing divide residentially between landlord and tenant due to the same energy metering systems or split incentive for the entire unit of apartment/house which hinders investment in energy efficient solutions. According to research carried out by SEAI, the majority of owner-occupiers in Ireland consider energy efficiency options but with alternative motives for investment other than energy consumption reduction (i.e., aspirational, comfort/value seekers and cost-driven). [1]

Currently, grid electricity and natural gas are the primary sources of energy for households, with a few older units still relying on oil and gas-based heating. An analysis conducted by the SEAI identified that energy savings potential through energy efficiency improvements is largest in the residential buildings sector (13.5 TWh) across all major energy-consuming sectors in Ireland. It is estimated that over 1 million homes need improving, while many needing refurbishments and retrofits to make them energy efficient. [1]

Research carried out by the SEAI demonstrates that up until the mid-2000s Ireland had one of the highest energy intensities per dwelling of any EU country. However, from 2006 to 2014 there were significant reductions in energy use in Irish homes. This reduction in household energy intensity was mainly a result of the economic downturn. Despite these energy reductions, after 2014 disposable incomes once again increased and oil prices reduced. In response to the easing of these pressures, residential energy use returned to growth between 2014 and 2016. [2]

It is in the government's interest to drive change in the residential sector as Ireland is subject to binding EU targets. These targets such as, the EU Green Deal main aim is to reduce greenhouse gas emissions and improve energy efficiency across the nation's housing stock. According to the SEAI, a total of 350,000 households have succeeded in upgrading to more energy efficient systems with government support through SEAI grants. A greater understanding of consumer behaviour and decision making can help enable the effective and efficient deployment of home upgrades across the country.

According to behavioural research conducted by the SEAI, there are a number interventions that have the potential to influence energy behaviours of the Irish populations, without the need for massive, large-scale interventions and retrofit schemes. The SEAI report has identified a number of strategies that have been proven to reduce energy usage in homes.

The provision of home energy reports was the most common household energy saving intervention identified by this review. Home energy reports summarise household energy use in an easy-to-understand format and compare it with the energy usage of their neighbours. This provides the householder with a frame of reference for their consumption and motivates occupants to reduce their energy consumption in comparison with their neighbours. A study carried out in the United States suggested that such home energy reports deliver energy savings of about 1-3%. [3]

Furthermore, another method for reducing energy consumption is to encourage households to set realistic energy saving goals and asking them to publicly commit to these goals. This method could potentially reduce electricity use by 10% in the short term. Goal setting and commitments can produce savings of between 4% and 22% of private household energy use, but, based on estimates, the average savings are more likely to be in the region of 10%. More work is needed to determine whether these savings persist in the long term. [4]

Time-of-use tariffs appear to either encourage households to use less energy or to shift their use to off-peak times. Increases in the peak tariff do not seem to lead to additional savings. Time-of-use tariffs charge for energy according to demand, and keep customers informed about prices. A number of studies reviewed the impact of providing homes with smart meters, in-home displays, time-of-use tariffs, demand–response programmes or a combination of these. The customer behaviour trials run in 2011 by SEAI, the Commission for Regulation of Utilities and other partners, to assess the savings associated with time-of-use tariffs, smart meters, and in-home displays, provided the most reliable evidence for the Irish context. The results showed that participants changed their energy use during different peak periods but did not further reduce their energy use when peak prices increased. Energy savings were largest when consumers received in-home displays in combination with energy-use statements and time-of-use tariffs. This combination yielded average energy savings of 3.2%, and reductions in energy use of 11.3% during peak periods. [5]

4.1.2 Offices

Currently, Ireland's medium sized organization possess a 41.2% energy efficiency improvement against the predetermined target of 33% which translates into savings equivalent of 24,000 tonnes of CO2 or €9M [6]. Similarly, the progress made by the smaller office-based organisations was at a 53% energy efficiency improvement against a target of 33%. The savings made are equivalent to 8,000 tonnes CO_2 or €3M [6].

In order to maintain this positive momentum, the government would have to employ sustainable and effective measures to maintain the energy efficiency improvement over the coming years. According to the SEAI, campaigns were identified to be an effective intervention for the business sector as they helped encourage energy saving trends leading up to 10% reduction in electricity use. These campaigns lead to energy savings ranging between 4% - 30%. There were a number of features which helped to implement these measures. These included goal settings, competition with frequent public ranking, comparative feedback across meaningful units (teams, departments, buildings, etc.), frequent feedback communications that include energy saving tips and weekly elected energy leaders who take responsibility for encouraging others to save energy for a particular week, and who are empowered to take energy saving actions like turning lights off.

There is also some evidence available on the effectiveness of independent energy audits. However, the research needs to be developed further. Providing businesses with free independent energy audits appears to increase investment in energy efficiency measure

According to the Department of Communications, Climate Action and Environment (DCCAE) there is a need to diversify government strategy for the upcoming targets of 2030. Behavioural change campaigns, smarter use of energy and some equipment upgrades have mostly driven energy savings. While this provided confidence on how much can be achieved through low-cost measures, the next energy savings will have to come from larger scale projects, such as deep renovation of buildings, Nearly Zero Energy new build, lighting and boiler replacement, upgrades to utility networks, fleet management and eco-driving. Behavioural change measures will of course also remain key to sustaining savings [7].

4.1.3 Public Sector Buildings

The Irish population has generally supported the government's policy and actions targeting climate change. There is relatively good amounts of awareness concerning the matters of the environment. The EPA conducted surveys in relation to climate change. Around 96% of Irish people accept and agree that climate change is happening [8]. The Irish population's commitment to climate action is reflected in the statistic that 57% have bought goods or services in the last 12 months from a company that has taken action to reduce climate change. Similarly, 45% have punished companies in the last 12 months that are opposing steps to reduce climate change by not buying their products [8].

Apart from the population trends, Irish public buildings have been faring relatively well in terms of performance. According to the 2021 Public Sector Energy Efficiency Report, public bodies avoided 6 million tonnes of CO2 emissions in the decade 2009-2020 [9]. An additional positive development was noted by the 2020 Annual Report on Public Sector Energy Efficiency Performance which highlighted that the public sector is 34% more energy efficient and exceeded its 33% energy efficiency target. This is the fourth consecutive year of continued improved performance from the public sector following the introduction of the Public Sector Energy Efficiency Strategy in 2017 [9] One of the primary targets outlined by the Climate Action Plan 2021 is a 51% reduction in energy-related greenhouse gas (GHG) emissions by 2030. The government and public bodies plan to collaborate in order to achieve the charted target through energy management schemes and comprehensive action roadmaps. Multiple policy actions are targeted at informed and efficient retrofitting of the existing infrastructure [9].

4.2 Building Codes and Regulations

The last 20 years has seen a plethora of energy conservation and decarbonization related policies, directives and regulations that attempt to pitch Ireland's response to the climate change crisis in a politically and economically sensitive framework. There are a number of departments and bodies responsible for implementing climate change policy in the built environment which are outlined in the table below.

Department/Organization Name	Abbreviation
Department of Housing, Local Government and Heritage	DHLGH
Department of Environment, Climate and Communications	DECC
Climate Change Advisory Council	CCAC
Sustainable Energy Authority of Ireland	SEAI
National Standards Authority of Ireland	NSAI
Office of Public Works	OPW
Office of Government Procurement	OGP

Table 4-1: Organization Responsible for Implementing Climate Change Policies

Improving energy performance of buildings is key to tackling the Climate Crisis and to achieving the EU Climate & Energy objectives. Member States must apply minimum requirements as regards the energy performance of new and renovated buildings, and energy certification of buildings when they are being leased or sold.

There are a number of standards and regulations that have been outlined by the government and with these it is important actions are taken in the building industry to achieve these ambitious targets. The purpose of this good-practice guide is to help practitioners to adopt such decarbonization principles in a way that protects and preserves the historic features of our existing buildings.

The home pages for our government departments play an important role in keeping the construction industry and the custodians of the built environment informed on what is now required of them when taking on new-build and conservation/renovation projects. These internet sites are now the main forum for dissemination, sharing and updating of standards and guidance documents. However, with each change of government, the departments that are responsible for the environment and for building regulations take on new responsibilities which often lead to considerable changes to their web sites. This results in considerable upheaval and confusion in the industry particularly when one considers the pace of new legislation being introduced in response to EU directives and regulations.

At a national level, the Climate Action Plan 2021 sets a roadmap for transitioning to a 'climate resilient, biodiversity rich and climate neutral economy by no later than 2050'.

4.2.1 Residential

According to the 2016 Irish census, there are currently over 2 million domestic dwellings in Ireland [10]. The Irish residential market has received significant support and aid from the government in terms of grants and free energy upgrades to counter the risk of energy poverty. In February 2022, the government launched the National Home Retrofit Scheme to make it easier and more affordable for homeowners to undertake home energy upgrades which would mean their homes would be warmer, healthier, and more comfortable while also lowering energy bills. This initiative was undertaken in line with the 2030 target of 500,000 home energy upgrades, to B2 Building Energy Rating (BER) standard.

As of October 2022, the government signed into law, revised planning exemptions for the installation of solar panels on the rooftops of houses and certain non-domestic buildings. The exemptions are aimed at increasing Ireland's generation of solar energy and combating climate change. These regulations aim to bring Ireland in line with the EU's solar rooftops initiative by permitting procedures for installing solar on rooftops shorter and simpler. It supports a target of installing up to 380MW (approximately 1 million solar panels) of microgeneration capacity as part of Ireland's overall solar targets under the government's Climate Action Plan. This would generate over 300 GWh of renewable electricity per annum, with the potential to abate 1.4 million tonnes of CO2eq over the lifetime of the installations. The regulations will also support the rollout of small-scale generation and act as an enabler for the Small-Scale Generation Support Scheme (SSG), which is expected to become available in 2023.

4.2.1.1 Grants

There are grants available to improve the energy efficiency of homes in Ireland. The SEAI administer these grants, which fall under 3 general schemes.

4.2.1.1.1 Better Energy Home Scheme

There are a number of grants which are accessible through this scheme. These include attic insulation, wall insulation, heating controls upgrade, solar thermal solutions, solar PV panels, heat pump systems and a BER after the energy saving work has been carried out.

4.2.1.1.2 Energy Upgrades for homeowners on low incomes

The SEAI provides free home energy upgrades to homeowners on low incomes. These home energy upgrades help improve the energy efficiency and warmth of your home. These free home energy upgrades are also known as the Better Energy Warmer Homes Scheme. This scheme covers home energy upgrades in terms of attic insulation, wall insulation, draught proofing, lagging jackets, energy efficient lighting and energy advice. New central heating systems and replacement windows are also occasionally covered by the scheme. Your windows will only be replaced if your walls are being insulated at the same time and the existing windows are single-glazed windows. The SEAI decides if replacement windows are needed on a case-by-case basis.

4.2.1.1.3 Home Energy Upgrade

The new National Home Energy Upgrade Scheme provides grants to upgrade the energy efficiency of your home. When the work is completed, each home should have an energy efficiency rating of B2 or above. The SEAI administers the grants, and a private company manages the work. These companies are called One Stop Shops, and the scheme is also known as the One Stop Shop Service. The scheme is carried out in partnership with private company registered with the SEAI. The company will manage the whole project, bringing each home up to a BER rating of B2 or above. The company will complete an initial energy assessment of the home and advise on the upgrades to bring it up to a B2 BER rating or higher while managing the work at each home ensuring that everything is up to standard. Following this, a final BER assessment will be carried out when the work is done

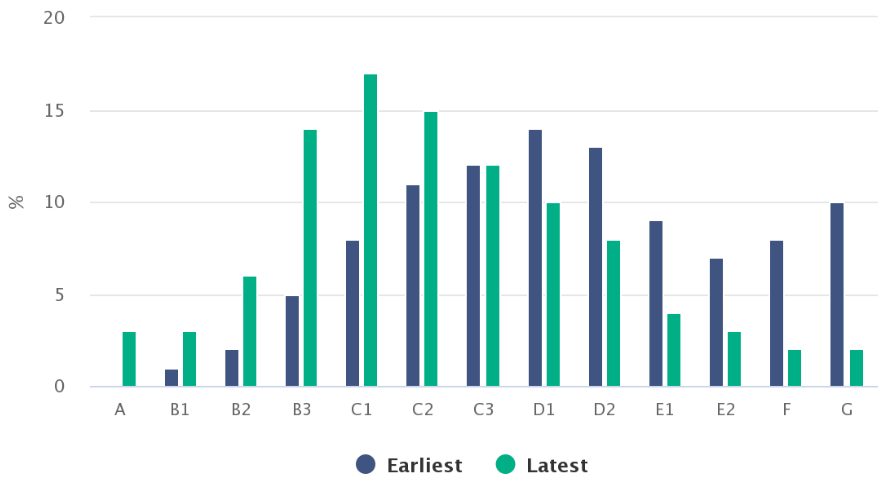


Figure 4-1: Earliest BER compared with the latest BER for dwellings with multiple BERS (2009 – 2021)

The figure above depicts the number of BER ratings carried out between 2009 and 2021. It is clear to see that in recent years there has been an increase in the number of BER ratings achieving higher results. With the implementation of government grants, it is expected that the number of dwellings obtaining a higher BER rating will increase significantly in the coming years.

4.2.1.2 Building Regulations – Technical Guidance Document L

Building regulations apply to the design and construction of a new building (including a dwelling) or an extension to an existing building. This Technical Guidance Document L details the importance of Conservation of Fuel and Energy – Dwellings (2022). When a new home is built, it must have 20% of primary energy as renewable energy in order to fully comply with building regulations. The guidance in the document applies to dwellings, both new and existing. This Technical Guidance Document outlines the energy performance requirements to achieve Nearly Zero Energy Buildings performance. The aim of Part L of the Second Schedule to the Building Regulations, and of the European Union (Energy Performance of Buildings) Regulations 2019 is to limit the use of energy and related carbon dioxide (CO_2) emissions arising from the operation of buildings, while ensuring that occupants can achieve adequate levels of lighting and thermal comfort. Buildings should be designed and constructed to achieve this aim as far as is practicable. Part L of the building regulations refers to the “conservation of fuel and energy” in your home [11].

4.2.2 Offices

The Energy Efficiency Directive concerns the development of an overview of the national commercial buildings stock, an evidence-based estimate of the potential energy savings within the commercial buildings stock and a strategy through which to achieve those energy savings in a cost-effective manner [12].

There are a number of key activities that must be carried out to develop a useful representation of the commercial buildings stock. Firstly, the frequency of the different types of buildings present must be established. Following on from this, data must be gathered on the fabric of these buildings, their condition, the energy services present and their occupancy. The lack of data concerning commercial buildings in Ireland causes a particular challenge with regards to the development of the building stock [12].

There have been a range of surveys carried out by different bodies to establish the different standards that different commercial offices are at in Ireland. Based on the survey results, the commercial buildings stock was derived in terms of five building activity types; office, retail and restaurant, warehouse and hotel. The following section outlines the main findings from a variety of surveys and analysis.

Figure 4-2: Number of Buildings per sector

All buildings with a gross floor area over 1,000 m^2 were classified as large-scale buildings and the remainder were classified as small. The total number of commercial buildings is estimated to be around 109,000, of which 82,000 are categorized as either Retail or Office [12].

4.2.2.1 Commercial Property - CSO - Central Statistics Office

There were 1,089 Building Energy Rating (BER) audits reported in quarter three 2021 compared with 879 in quarter three 2020. This is an increase of 24%. The results obtained by the CSO aid with determining what steps must be taken to ensure that Ireland decrease energy consumption by 50% by 2030.

Year	Heat pumps in Residential Buildings
2021	13000
2022	33500
2023	55000
2024 - 2030	56215

Table 4-2: Number of Residential Buidlings Expected to be Retrofitted to BER B2 per Annum (or carbon equivalent)

4.2.2.2 Building Regulations –Part L - Buildings other than Dwellings

Since the first of January 2019, the new 2017 Building Regulations for Part L – Conservation of Fuel and Energy – Buildings other than Dwellings, has come into effect. One aspect of the technical guide analyses the minimum standard of insulation required in a building. If the building requires planning permission, it must comply with these standards. Each level of the building has their own maximum U-Value requirement. U-Value being a measure of the heat transmission through a building part i.e. the amount of heat that is lost, the lower the U-Value the better, as less heat is lost. The technical guide outlines the max U-Values as part of the new Part L regulations. Part L applies to all works to existing buildings other than dwellings that are covered by the requirements of the Building Regulations, including extensions, material alterations, material changes of use, major renovations and window and door replacement. In carrying out this work, the aim should be to limit energy requirements for the operation of the building and associated CO_2 emissions as far as practicable as required by Regulation L1 [13].

4.2.3 Public Sector Buildings

In the Programme for Government and the Climate Act 2021, Ireland committed to halving greenhouse gas emissions by 2030 and reaching net zero by 2050 at the latest. There are about 12,500 public sector buildings that account for approximately half of the public sector's overall Greenhouse Gas emissions. All public sector bodies other than schools, local authorities and commercial semi-states must produce Climate Action Roadmaps by the end of 2022. The Action Plan notes that in order to achieve the 51% emissions reduction and 50% energy efficiency targets, buildings will need to undergo a deep retrofit. In relation to public sector buildings, the Action Plans seeks to develop a strategy to achieve at least a 51% reduction in Greenhouse Gas emissions and a 50% improvement in public sector energy efficiency by 2030.

Due to the wide range of the OPW building types, uses and historic significance it is very difficult to achieve a one-size-fits-all solution to upgrading the whole portfolio. The strategies employed to improve the performance of a simple warehouse used for storage will inevitably be different to those employed in an office located within a 19th Century former townhouse. Even within similar use classes, any strategy that may be undertaken to address a late 20th Century concrete frame office building, such as Tom Johnson House, may not be suitable to address an early 18th Century solid masonry building. Furthermore, upgrading the thermal performance and energy efficiency of the existing building stock presents numerous challenges, particularly where the building was built using traditional materials and construction methods and is of architectural and/or historical interest. In such cases, additional considerations are warranted. While an upgrade strategy to a building may be based on the set of principles discussed below, each building must be taken on its own merits and a specific approach developed that will address the particular criteria required without having a negative impact on the building or structure.

To reduce emissions in line with national and international targets, Ireland's building stock will need to be highly energy efficient and largely decarbonised by 2050. This means new buildings must be NZEB standard and existing buildings must be retrofit.

The NZEB standard will apply to all new buildings occupied after the December 31st 2020. For Public Sector bodies, the standard will apply to all new buildings owned and occupied by December 31st 2018. 'Nearly Zero Energy Buildings' means a building that has a very high energy performance. The nearly zero or very low amount of energy required should be covered to a very significant extent by energy from renewable sources, including energy from renewable sources produced on-site or nearby [14]. The recast of the recast Energy Performance in Buildings Directive will see the NZEB term change to ZEB, meaning 'Zero Emissions Buildings'. This clarifies 2 key points: 1. That it is unlikely that a building will ever be able to be zero energy given the constraints in an urban setting to generation of renewable energy, and 2. The embodied carbon of buildings needs to be accounted for as well as operational carbon emissions.

For all new builds, an equivalent of a 60% improvement in energy performance on the 2008 Building Regulations is required. This means an improved energy performance for the fabric, services, and lighting specification. It also introduces a mandatory requirement for renewable sources. The renewable sources must in general provide 20% of the primary energy use, however there is flexibility where the building is more energy efficient than the regulations [14].

The CAP2021 action 56 will see renewed pressure to get Display Energy Certificates in place for public sector buildings. Energy reporting and comparison against the predicted energy use through the BER will provide important feedback on building performance for retrofitting of historic buildings.

4.3 Energy market rules and tariffs

4.3.1 Current Energy Network

In 2018, Ireland's electricity sector was responsible for 16.2% of the national greenhouse gas emissions (GHG). With the charting out of the Climate Action Plan 2021, the government aims to decarbonize the electricity sector by transitioning to renewable energy resources through cost competitive channels and insulate Ireland's electricity to external shocks such as those caused by the price of fossil fuels. The purpose of this shift is not only to enhance the energy security of the country but to also satisfy the EU-wide targets that are legally binding. In accordance with the Emissions Trading Scheme requirements, emissions from electricity generation must be reduced by 43% by 2030, relative to 2005 levels [15]. In the recent decade, Ireland has embarked on a progressive reduction of emissions caused by electricity. Between 2005 and 2018, Ireland saw an overall one-third reduction in electricity emissions with a subsequent growth in its renewables sector and higher efficiency conventional generation. From 2011 to 2018, there was an absolute change of 1.4 MtCO2eq which was a result of a 11.8% decrease in GHG emissions. Around the same time period Ireland's renewable energy sector saw a five-fold growth jumping from 7.2% to 33.7% within 13 years and seeing a 1,873 GWh of renewable electricity generation in 2005 to 11,780 GWh in 2019 [15]. This increase in the share of renewables came despite a rise in the total demand for electricity.

In the context of Europe, Ireland's share of electricity emissions per person were 13% above the EU average, due to the use of high-carbon fuels, such as coal and peat. By 2018, Ireland's electricity emissions per person had greatly reduced close to the European average. To meet the required level of emissions reduction targets set out by the Climate Action Plan, by 2030 Ireland plans to incorporate renewable energy systems to its energy infrastructure. This provides a significant window of opportunity to the RES4BUILD's market offering. Currently, Ireland's total electricity demand over the next 10 years is forecast to grow by between 19% and 50%, largely driven by new large energy users, many of which are data centres, based on existing policies and strategies [15]. Therefore, it can be positively predicted that the electricity demand will almost double by 2030. However, in conjunction with this high scenario growth – the policy actions in place would help reduce the electricity emissions by 60-80% at the same time. According to the current strategy laid out by the Climate Action plan, the proposed pathway of decarbonizing the electricity sector includes a more rapid build-out of renewable generation capacity (wind and solar power generation technologies), increased storage, and the deployment of zero-emissions gas. The decarbonisation pathway for the electricity sector is challenging given the rapid growth in demand for power, as well as the need to ensure security of supply through the decarbonisation journey.

4.3.2 Renewables

According to the SEAI, Ireland had a target for at least 16% of gross final energy consumption (GFC) to come from renewables by 2020. This is commonly referred to as "the overall renewable energy share (RES) target" and was a mandatory target under the EU Renewable Energy Directive (RED). The actual overall renewable energy share in 2020 was 13.5%, meaning that Ireland did not meet its overall RES target [16].

However, in terms of electricity generation from renewables, Ireland has achieved considerable success. Renewable energy sources are now the second largest source of electricity after natural gas. Without any requirement of any EU binding law, Ireland set an ambitious national target of 40% for itself and in 2020, 42% of electricity came from renewable sources. Moreover, electricity generated from hydro and wind varies depending on rainfall and wind conditions. To even this out, the Renewable Energy Directive averages the wind and hydro output over a number of years. Using this methodology, the renewable energy share in electricity (commonly known as RES-E) was 39.1% in 2020, falling just short of the 2020 target [16].

The replacement of fossil fuels with renewable zero-carbon energy sources is essential for reducing greenhouse gas emissions such as carbon dioxide. It also improves energy security by reducing the reliance on imported fossil fuels. The amount of CO_2 avoided using renewable energy increased five-fold between 2005 and 2020, reaching 6.6 million tonnes of CO_2 ($MtCO_2$) avoided in 2020. This was equivalent to the CO_2 emissions of over half of all Irish homes. Eighty-four per cent (84%) of CO_2 emissions avoided by the use of renewable energy in 2020 were from renewable electricity. Wind generated electricity alone was responsible for 68% of all avoided CO_2 emissions, avoiding 4.5 $MtCO_2$. Decarbonising the electricity system combined with increased electrification of heat and transport, for example through electric vehicles and heat pumps, is a crucial part of the strategy to decarbonise the energy system. The use of renewable electricity ensures that switching to electric vehicles and heat pumps results in significant reductions in CO_2 emissions compared to the fossil fuel alternative [16].

According to the Climate Action Plan 2021, renewable energy is highlighted as a key to decarbonising the energy sector [15]. Ireland has significant renewable energy resources, with wind energy accounting for 36% of the country's electricity in 2020. Ireland currently has an installed wind capacity of 4.2 MW. The Climate Action Plan commits to increasing this to 13 GW (combined onshore and offshore wind) by 2030. In support of achieving large scale renewable generation measures will be undertaken.

A new Offshore Renewable Energy Development Plan (OREDP II) will be completed to quantify the offshore renewable energy potential in Ireland's maritime area. The OREDP II will also provide an evidence base for the assessment of areas suitable for deployment of offshore renewable energy. The Maritime Area Planning (MAP) Bill, which has since been enacted, has put in place a comprehensive and coherent marine planning regime for the development of offshore renewable energy in the maritime area. The roll out of regular competitive auctions under the Renewable Electricity Support Scheme (RESS) to deliver targets and ensure a steady supply pipeline of projects and efficient use of the network. There will be an estimated 500 MW of renewables generated through local community-based projects by 2030.

Despite a public consultation run between 2008 and 2009, heavily influenced by the work and results of the GTRH project, a regulatory framework for geothermal energy in Ireland is still absent. The lack of clarity on permitting requirements (shallow or deep) is therefore a clear barrier for geothermal. Where an abstraction license is required (generally the case for larger schemes) applications are to the local authorities. A centralised licensing and regulatory body should be responsible for geothermal energy and district heating (but this is against the current policies of decentralisation that are being implemented).

There is currently no legal framework for the regulation of geothermal energy in Ireland, other than the Planning and Water Pollution legislation. In 2006 and 2007 leading players in the geothermal industry contacted the Department of Communications, Energy and Natural Resources (DCENR) and expressed concerns that Ireland would be at a serious disadvantage in comparison to almost all other developed economies in relation to a regulatory structure for the exploration for and exploitation of sources of geothermal energy. The main concerns centred around: uncertainty of title and protection of investment.

4.3.3 Microgeneration Support Scheme

Micro-generation is the general term used to refer to the generation of electricity from renewable technologies including solar photovoltaic (PV), micro-wind, micro-hydro and micro-renewable combined heat and power (CHP).

A payment, or Clean Export Guarantee (CEG), is available to all renewable generators that export to the grid, regardless of what energy provider they have a supply contract with. The Commission for Regulation of Utilities (CRU) published a decision on an interim enabling framework for the CEG on 1 December 2021. Under the Climate Action Plan 2021, a Microgeneration Support Scheme (MSS) was approved by the government on 21 December 2021. Applications for domestic solar PV grants can be made at the through SEAI. Smart meters and smart infrastructure are essential to the delivery of the benefits of the energy transition, including for micro-generators. Smart meters can measure the profile of demand at the premises and thereby allow micro-generators to maximise their self-consumption. Smart meters can also measure the export of micro-generation installations to facilitate access to remuneration for residual electricity exported to the grid.

The SEAI has a Better Energy Communities Scheme which is a national retrofit initiative with grant support for energy efficiency and renewable measures, including Solar PV installations. Through this scheme, support in achieving energy efficiency and reduced energy use and costs can be delivered for homeowners, communities, and private sector organisations [17].

5 Appendix E: Italy

5.1 Cultural, economic, and social aspects

5.1.1 Decarbonisation scenario and policies

In Europe, from the point of view of total CO_{2e} emissions, there is a downward trend, particularly from 2005 onwards. Since 1990, EU emissions have fallen by 26%, and in the last stretch, the downward curve has become steeper (-21% compared to 2005 levels). The signal can undoubtedly be interpreted in favourable terms, but always bearing in mind the size of the target. In Italy, the situation is even more peculiar. 2005 was the highest emissions year since 1990 (with 591 MtCO2eq emitted), and the overall reduction, compared to 1990, has stopped at 20%, six percentage points less than in Europe.

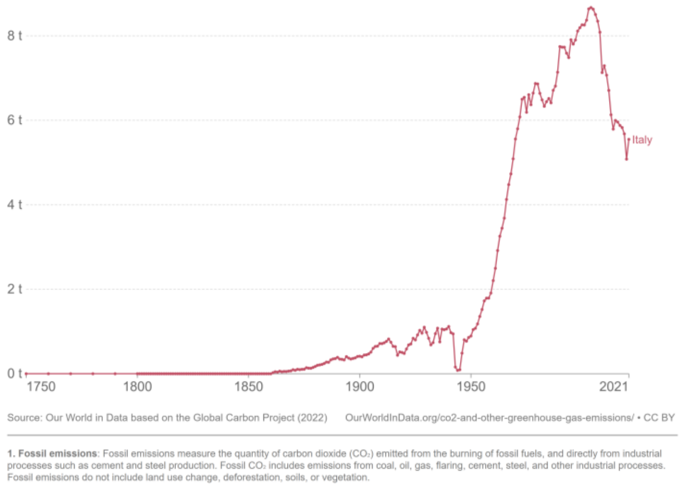


Figure 5-1: Per capita CO_2 emissions from fossil fuels and industry (Italy: C_O2 Country ProfileItaly: CO_2 Country Profile, 2021)

This figure must therefore raise some concern, especially if one looks, as shown in the following graph, at the distribution of emissions in our country, with electricity and heat, transport and building sector covering the greater part of the emissions.

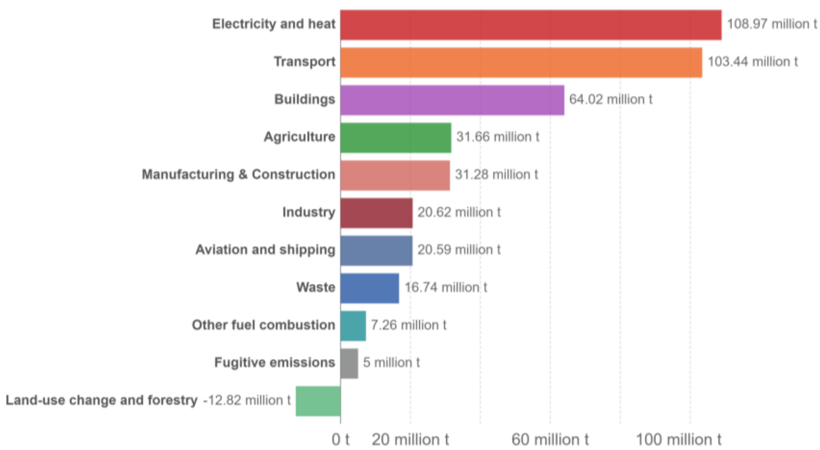


Figure 5-2: Greenhouse gas emissions by sector (Italy: C_O2 Country Profile, 2019)Greenhouse gas emissions by sector (Italy: CO_2 Country Profile, 2019)

SETTORE	2005 [$MtonCO_{2eq}$]	AS-IS [$MtonCO_{2eq}$]	Delta 2005 vs AS-IS [$MtonCO_{2eq}$]	Riduzione emissioni - 55%: 2030 [$MtonCO_{2eq}$]	Riduzione emissioni - 55%: Delta AS-IS vs 2030 [$MtonCO_{2eq}$]
Produzione di energia e calore	160	92	68	62	30
Industria	92	50	42	41	9
Trasporti	128	105	23	46	59
Residenziale, commerciale e servizi pubblici	87	73	14	32	41
Altri consumi di industrie energetiche	11	7	4	6	1
Processi Industriali	47	34	13	18	16
Agricoltura	43	39	4	21	18
Rifiuti	22	18	4	8	10
TOTALE	**590**	**418**	**172**	**234**	**184**

Figure 5-3: Greenhouse gas emissions per sector – 2005 and 2030 comparison (Zero Carbon Policy Agenda ReportZero Carbon Policy Agenda Report – Energy & Strategy group School of Management, Politecnico di Milano)

According to the analysis of the national emissions situation, it is possible to identify 6 priority macro-areas for achieving decarbonisation targets set by both EU and Italian regulations.

- Renewable energy production;
- The upgrading of grid infrastructure;
- Energy efficiency;
- Sustainable mobility;
- The development of efficient configurations (energy communities);
- The adoption of the circular economy paradigm.

5.1.2 Regulatory trend and main aspects

In line with - and spurred by - constant updates of European decarbonisation regulations, Italy has adopted, through national regulations, such as the Piano Nazionale Integrato per l'Energia e il Clima (PNIEC), the Piano Nazionale di Recupero e Resilienza (PNRR), the Strategia di Lungo Termine and the Piano per la Transizione Ecologica (PTE).

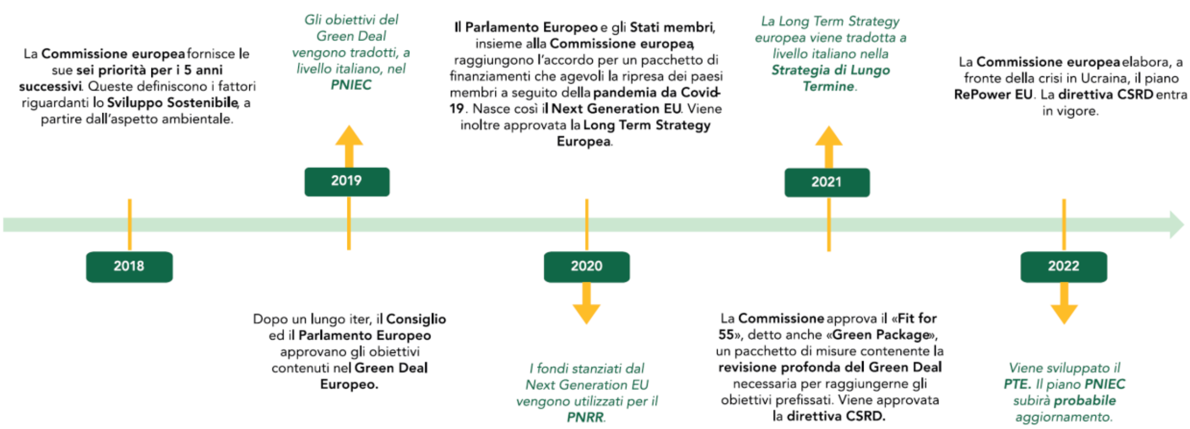


Figure 5-4: EU and National implementation of energy-related regulations (Zero Carbon Policy Agenda ReportZero Carbon Policy Agenda Report – Energy & Strategy group School of Management, Politecnico di Milano)

The PNIEC (National Integrated Energy and Climate Plan) was published in December 2019 and is the only official and binding document at the national level that sets out the targets for the three main areas of the energy sector (generation from renewable sources, energy efficiency and emission reduction).

It is structured along five integrated lines of action: Decarbonisation, Energy efficiency, Energy security, Development of the internal energy market and Research, innovation and competitiveness.

However, it should be emphasized that the debate that has been going on in recent months, both among practitioners and at the institutional level, considers the PNIEC targets only as minimum objectives to be achieved to reach the more ambitious 2050 climate neutrality target.

As stipulated in the European Green Deal, this target requires a more stringent greenhouse gas emission reduction target for 2030. For this reason, the targets set by the PNIEC will necessarily have to be updated 'upwards' and, above all, take into account a longer time horizon.

The main objectives set by the PNIEC for Italy are summarized below:

- Reduction of greenhouse emissions by at least 40% at the EU level compared to 1990 (-33% compared to 2005). The target is divided between the ETS sectors (energy-intensive and aviation industries) and non-ETS (transport, residential, tertiary, non-ETS industry ETS sector, agriculture and waste).
- Increase the share of energy produced by RES in the gross final energy consumption by 30%.
- Reducing consumption by 43% of primary energy and 39.7% of final energy compared to the PRIMES 2007 reference scenario.

In order to meet the ambitious targets, set out in the 'Fit for 55' package, which raises some of the macro targets contained in the European Green Deal, it is necessary to revise the PNIEC targets upwards. A revision is therefore planned, which is currently being drafted and should be published in 2022.

Pending this update, the Ministry of Ecological Transition has adopted the Plan for Ecological Transition (PTE), which provides an environmental and energy policy framework integrated with the objectives already outlined in the National Recovery and Resilience Plan (PNRR).

According to the government plan, the European Recovery and Resilience Facility amount is EUR 191.5bn (EUR 68.9bn in grants and EUR 122.6bn in loans) for the period 2021-2026. To these are added a further EUR 30.6bn, forming part of a Supplementary Fund, financed through the multi-annual budget slippage approved by the Council of Ministers on 15 April, and EUR 13bn made available by REACT-EU. The total resources in the Italian NRP thus amount to EUR 235.1Bn.

The Plan identifies 6 Missions, which are in turn divided into 16 Components, functional to achieving the economic and social objectives defined in the Government's strategy. For Mission 2, 'Green Revolution and Ecological Transition', the NRP allocated EUR 59.33 billion, divided into 4 Components, the third of which is 'Energy Efficiency and Renovation of Buildings', clearly identifying the country's needs.

In this context, the proposed Long-Term National Strategy (LTS) identifies possible pathways to achieve 'climate neutrality' in our country by 2050, in which residual greenhouse gas emissions are offset by CO2 removals and the possible use of geological storage and reuse of CO2 (CCS-CCU).

Whitin Italy’s Long-Term Strategy, a forecast has been made of how the Italian energy balance is expected to change by 2050, compared to the situation in 2018, thanks to the Decarbonisation Scenario:

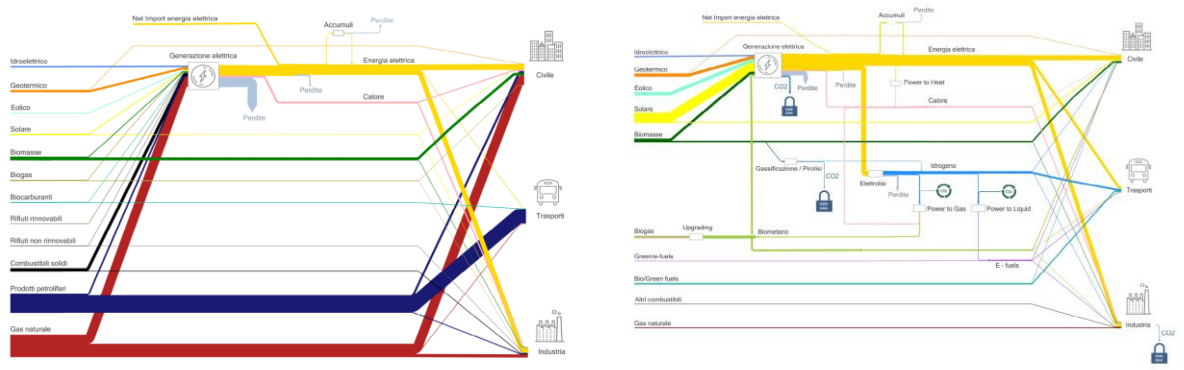


Figure 5-5: Italy energy balance 2019 – 2050 comparison (Strategia di Lungo Termine, 2021)

5.1.3 Renewable energy integration

Renewable targets were increased during 2021 by the 'Fit for 55%' package, which contains the legislative proposal to achieve the European Green Deal target of reducing emissions in Europe by at least 55% by 2030. As a result, increasingly ambitious targets are being set, revising the PNIEC targets as indicated in the Ministry's PTE, which calls for an increase to 72% of renewable sources in electricity generation (vs PNIEC target of 55%) and to install around 70 GW of additional renewable power plants by 2030. The expansion of the renewables market, although it did not come to a complete halt even during the year most marked by the Covid-19 pandemic, picked up again in 2021 thanks to the growth of new installations both worldwide and in Europe. This continuous increase in renewables capacity has brought Europe ever closer to the 700 GW mark.

As far as Italy is concerned, in 2021 the country showed an increase in new installations that had been at a 'standstill' since 2018, but the growth values recorded are only justified by the recovery following the pandemic and see new installations in photovoltaic and wind power plants realigned to the numbers observed in 2019. The new renewables capacity installed in Italy during 2021 was 1,351 MW (well below the 7 GW/year to be met to be aligned with National target to 2030), with an overall increase in installations of +70% in terms of capacity compared to 2020 (790 MW), taking the country past the 60 GW threshold of total renewables. The increase was driven primarily by new photovoltaic capacity of +935 MW (+30% compared to 2020), followed by wind power, which recorded the most marked growth (+404 MW); this was followed by hydroelectric power, which, with a more modest growth (+11 MW), confirms the stable trend it has been following for several years, and bioenergy, which instead recorded a decrease (-14 MW). A decisive return to the growth of installations, combined with the management of the existing park, is therefore increasingly urgent to prevent the gap with the decarbonisation path from widening further, making it increasingly difficult to correctly reach the 2030 target.

Moreover, some progress was made during 2021 regarding the regulation of renewable plant installations, mainly in simplifications and access to incentives for photovoltaic plants, while less progress was made in simplifications for wind power plants. The simplifications, however, were introduced by several decrees that followed one another (DL Semplificazioni, DL Semplificazioni bis, DL Energia).

In fact, during 2022 an additional increase in installation can be noted, with over 1,200 MW installed in the first 6 months, with a trend of doubling the installed and connected renewable power respect to 2021. In addition, Terna, the Italian electrical grid manager, declared that over 250 GW of renewable sources have requested to be connected to the national grid: even a limited percentage of those requests would be enough to fulfil Italy requirements up to 2030 and beyond, but the new developements are slowed down by authoritative processes, managed by multiples subject on different territorial scale (national, regional, local, municipal).

With the transposition of the REDII Directive (Legislative Decree 199/2021), further novelties, simplifications and regulatory details were introduced. The authorisation procedures have been reduced to four (the Free Building Communication, the DILA, the PAS[90] and the Single Authorisation) to overcome the difficulties associated with authorisation processes that differ from region to region. The incentive mechanisms have been reorganised, and new regulations have been introduced for auctions, registers and energy communities: concerning the latter, the number of actors that can participate in renewable energy communities has been broadened (with the introduction, for example, of religious bodies and the third sector), the participation of already existing plants is allowed (for a share not exceeding 30% of the total power) and plants located in buildings or in sites other than those where the self-consumer operates, shifting from producer-consumer approach to pro-sumer approach, where multiple small subjects are able to produce and consume energy during different part of the day and the year.

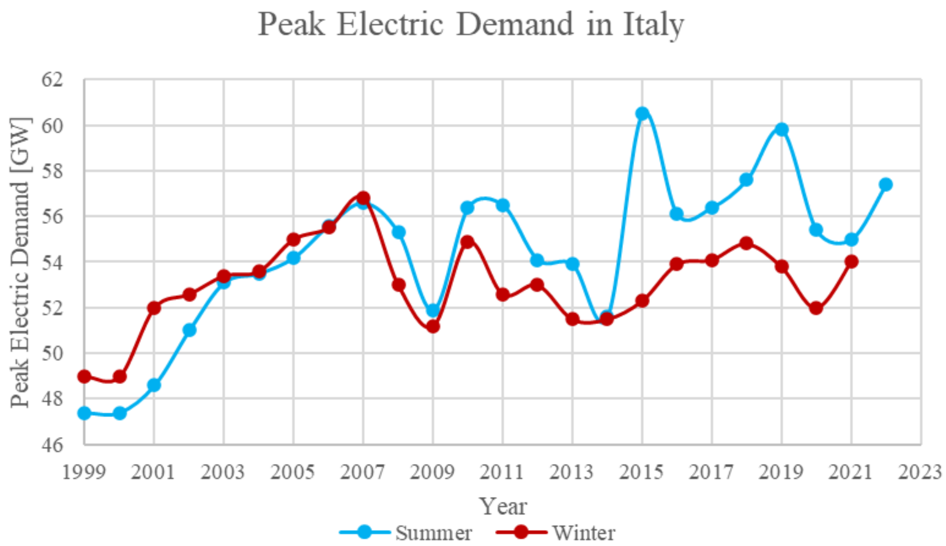
Another potential opportunity for the increase of renewables in Italy is represented by the PNRR, which through the C2 component of the 'Green Revolution and Ecological Transition' Mission, dedicates EUR 25.36 billion to the themes of renewable energy, hydrogen, grid and sustainable mobility. In particular, there are four areas of intervention related to increasing the RES share: the development of agro-voltaics (EUR 1.1bn), Energy Communities in small municipalities (EUR 2.2bn), the promotion of innovative plants (EUR 0.68bn) and the development of biomethane (EUR 1.92bn).

It appears, however, that the investment areas in the National Recovery and Resilience Plan refer to specific projects and are, therefore, not a structured plan for the development of renewables but rather a start-up support for specific sectors. Moreover, the calls are mainly addressed to private entities or the Public Administration, whereas to maximise the chances of success of the PNRR calls, the involvement of energy entities, which can provide technical and financial support to public and private entities, should be simplified and systematised.

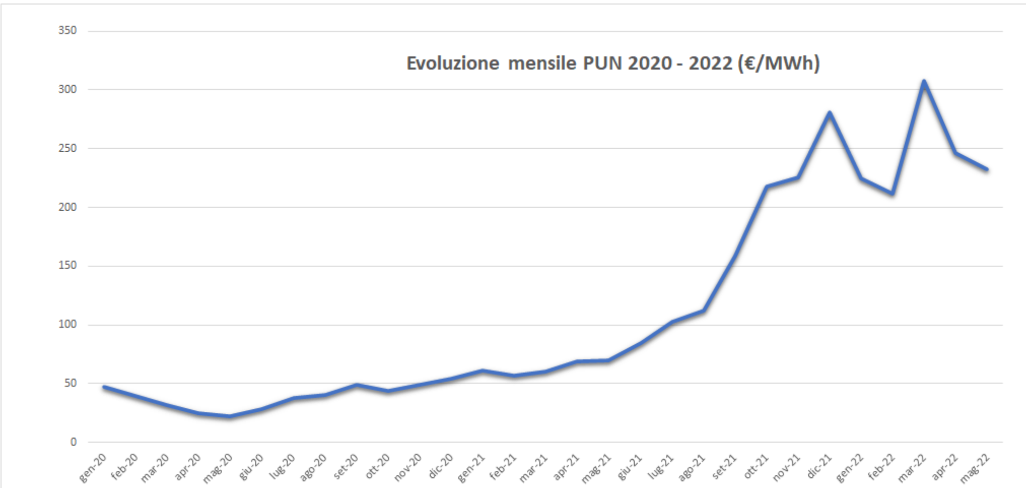
5.1.3.1 Population approach to sustainability and energy efficiency

Analysing medium-term trend, it is possible to highlight a progressive shift in energy demand from winter to summer: reasons are complex and cannot be analysed in detail in this report, but a part of the solution is related to the increasing request for cooling in every household, office, and retails space. In fact, since 2007 the summer peak electric demand is greater respect to winter one, with a progressive and increasing gap between winter and summer peak.

[90] For ground-mounted photovoltaics in suitable areas, for installations of up to 1 MW, a sworn declaration of work commencement (DILA) will suffice, and up to 10 MW the simplified enabling procedure (PAS). These procedures are defined in the Energy Decree (dl 17/2022) and aim to simplify the installation of solar panels (photovoltaic and thermal) on roofs and roofing: it is considered 'ordinary maintenance work' and is not subject to the acquisition of permits, authorisations or administrative acts.



In addition, in the last years, the energy cost has experienced a very variable trend, due to covid pause, post-covid restart and recent war in Ukraine, with energy cost (the mere cost related to energy, not considering taxes and other components) rising even 7 times respect to pre-covid period. In Italy the PUN index (*Prezzo Unico Nazionale* - Single National Price) is a relevant indicator, affecting families and industries energy expenditure, with energy cost for MWh passing from 40-50 € to more than 350 €.



Given the previous aspects penetration of renewable sources and highly efficient building services (e.g. heat pumps) has a constant increasing trend, highlighting indication of privates, even without illimited capital expenditure, to avoid the use of any fossil fuel both for building but also transport.

The joint installation of large arrays of photovoltaic panels with heat pump, together with moderate winter temperature and high sun irradiance, allows consumers to switch from fossil fuel to renewable sources for heating, cooling, domestic hot water, appliances, and lighting. Another increasing trend is related to transport, electric car in particular, being able to be charged at home or during workhours within new office developments allowing relevant savings due to gasoline and diesel, especially if batteries can be integrated in the project. At the same time, complex regulations on different geographical levels and managed by different subjects is an obstacle to broad and deep penetration of renewable sources, with main drivers and concepts poorly understood by the general public. For example, there is the misplaced idea, even within sector professionals, that produced but unused renewable electricity sold to the public network is valued with a non-competitive tariff: in fact self-produced electricity could provide relevant incomes due to the high energy prices of the recent period, shortening payback-time (return of investment) in a relevant way.

At the same time, large developers, the only ones able to implement large integrated energy networks, aiming to completely decarbonize new developments, are considering a new approach for heating and cooling at district level. First example is Porta Nuova in Milan (developed by Coima), using ground water for water-to-water heat pumps, avoiding any use of fossil fuel onsite since the 2010s, even if the Community is not fully decarbonized due to the limited number of renewable sources integrated onsite.

New developments in Milan by Lendlease and Redo Sgr, in different developing phases, will be net zero by using different strategies of heating and cooling generation, extensive renewable sources integration and building materials with a limited carbon footprint (as timber or materials with high-share of recycled content). In detail: Redo is developing the first net zero social housing, collaborating with A2A, the energy company of Milan; while Lendlease is developing two large brownfield areas of Milan: MIND - Milano Innovation District and MSG - Milano Santa Giulia. The first one is implementing a system called Eon ectogrid[91] to manage heating and cooling demand with a low temperature/low enthalpy network, together with an electrical smartgrid managed by Enel X; the second one will be a net zero development with a fully geothermal based DH/DC network, large PV installation and optmised construction technologies.

Also private subjects are interested in renewable integration: reasons are various, but in general, the main ones are aiming to increasing their independency from other subjects and to reduce operational expenditure related to energy consumption, reducing their carbon footprint is a secondary target, even a smaller part of private subjects is already fully committed to due to their professional background, or job and skills. There are relevant incentives (explained in the following sub-chapter) supporting private residential sector in refurbishment, aiming to reduce overall energy consumption and increase renewable penetration in the sector.

5.2 Building codes and regulations

The Italian regulatory framework in the fields of energy efficiency and renewable energy, both for new buildings or consistent renovations, is quite various and complex. Regulations are declined on different levels: **National, Regional and sometimes even Municipal**.

In the following chapters we will try, albeit simplifying the dissertation, to report the regulations that are more relevant and that have had the greatest impact on the specific issues discussed in this paper.

5.2.1 National Regulation

5.2.1.1 Ministerial Decree of June 26th, 2015 (or D.M. 26/06/2015)

On energy efficiency, the European Community has shown member countries the way forward with the **Energy Performance Buildings Directive (EPBD)** 2002/91/EC, later updated with Directive 2010/31/EU (EPBD2) and Directive 2018/844/EU. Italy transposes EPBD guidance through Legislative Decree 192/2005, Decree Law 63/2013 (converted by Law 90/2013), the **Ministerial Decree of June 26, 2015**, and Legislative Decree 48/2020.

[91] https://www.eon-energia.com/eon-business/industria/mind.html

The first regulation at national level that it is worth to be mentioned is the **Ministerial Decree of June 26/2015 "Application of energy performance calculation methodologies and definition of prescriptions and minimum requirements for buildings"** (*Decreto Ministeriale "Applicazione delle metodologie di calcolo delle prestazioni energetiche e definizione delle prescrizioni e dei requisiti minimi degli edifici" del 26 giugno 2015*), from now on called D.M. 26/06/2015.

The D.M. 26/06/2015, defines how to apply the methodology for calculating the **energy performance of buildings**, including the use of renewable sources.

The Decree applies to public and private buildings, and is not related to a specific type of use (e.g., residential, educational, commercial etc.) but to the **intervention type**. They can be summarized in 3 main categories of influence:

- **New construction** (including demolition-construction and addition of new portions of building where the volume of the extension exceeds 15% of present volume or is higher than 500 sm)
- **Major renovations** (affecting only building envelope that delimit conditioned volume from the external environment and from non-temperature-controlled environments)
- **Energy retrofit** (renovation of a heating-cooling system subservient to the building or other partial work, including replacement of the generator).

According to calculation methodologies for the D.M. 26/06/2015, **Energy Performance** of buildings belonging to the above-mentioned categories is measured according to the indexes expressed below:

- H't [W/m^2 K]: overall average coefficient of heat transfer by transmission per unit of dispersing surface area.
- $A_{sol,est}$/ $A_{sup,utile}$ [-]: summer equivalent solar area per unit of usable area.
- $EP_{H,nd}$ [kWh/m^2]: Useful thermal performance index for heating.
- $EP_{C,nd}$ [kWh/m^2]: Useful thermal performance index for cooling.
- $EP_{W,nd}$ [kWh/m^2]: Useful thermal performance index for domestic hot water production.
- η_H [-]: Average seasonal efficiency of the winter air conditioning system.
- H_W [-]: Average seasonal efficiency of the hot water production system domestic hot water.
- η_C [-]: Average seasonal efficiency of the summer air conditioning system (including humidity control).
- $\mathbf{EP_{gl,tot}}$ [kWh/m^2]: **global energy performance index** (combining <u>Non-Renewable and Renewable Primary Energy</u>), which is obtained as follows:

$$EP_{gl} = EP_H + EP_W + EP_V + EP_C + EP_L + EP_T$$

$\mathbf{EP_H}$ [kWh/m^2]: Energy performance index for winter air conditioning system;
$\mathbf{EP_W}$ [kWh/m^2]: Energy performance index for domestic hot water production;
$\mathbf{EP_C}$ [kWh/m^2]: Energy performance index for summer air conditioning, including humidity control, if any;
$\mathbf{EP_V}$ [kWh/m^2]: Energy performance index for ventilation;
$\mathbf{EP_L}$ [kWh/m^2]: Energy performance index for artificial lighting;
$\mathbf{EP_T}$ [kWh/m^2]: Energy performance index for vertical transportation.

A first feature of the Italian framework is thus evident, namely that the calculation of the energy performance of buildings is based on **Primary Energy**, both Renewable and Non-Renewable.

For design verifications of compliance with the Minimum Requirements, the calculation of both of total primary energy and non-renewable primary energy, obtained by applying conversion factors, is performed. Instead, for the purpose of building classification (EPC rating), the calculation of non-renewable primary energy is carried out.

Therefore, some important conclusions about the regulation to be highlighted from the above-mentioned requisites:

a. According to D.M. 26/06/2015, performance of buildings is determined based on the amount of energy required annually to meet the needs associated with a standard use of the building and corresponds to the overall **annual energy demand in Primary Energy** for heating, cooling, ventilation, domestic hot water, and, in the nonresidential sector, for lighting, elevator and escalator systems.
b. it is permissible to consider energy from renewable (compensation Offsetting between energy needs and energy from renewable sources) or cogeneration sources produced within the system boundary (in situ) only to contribute to the needs of the same energy carrier (electricity with electricity, thermal energy with thermal energy, etc.) and up to full coverage of the corresponding requirement or energy carrier used for the services considered in the energy performance (the surplus of energy over the monthly requirements, does not contribute to the energy performance of the building).
c. Calculation is made of both of total primary energy and non-renewable primary energy.

In addition to these topics (but not discussed in this paper, as not relevant) the Decree also covers the insulation part of the **thermal envelope**, establishing reference thermal transmittances (U-values in W/m^2K).

5.2.1.2 *Legislative Decree No. 199 of December 15th, 2021 (or D.Lgs. 199/2021)*

Another important Decree that needs to be mentioned at National Level is the **Legislative Decree No. 199 of December 15th, 2021** "Implementation of Directive 2009/28/EC on the promotion of the use of energy from renewable sources" which, taking effect from June 13, 2022, replaced the previous D. Lgs.28/2911.

From June 2022, the **minimum allowable threshold for renewable energy** in both new buildings and those undergoing major renovation has been changed. The mandatory coverage from renewable sources of energy consumption for private buildings **has been increased to 60% (up from the previous 50%)**, while for public buildings the share has been increased to 65%.

The Legislative implemented **EU Directive 2018/2001 "Promotion of the use of energy from renewable sources"** (known as RED II). The provisions for new construction and renovated buildings refer to all types of renewables in use today in construction: solar, thermal, wind, geothermal, hydroelectric or biomass energy. In particular:

- **Thermal Renewable**: new buildings or buildings undergoing major renovation shall be designed and constructed to ensure, using systems powered by renewable sources, simultaneous compliance with the coverage of 60% of the planned consumption for the production of **domestic hot water** and 60% of the sum of planned consumption for the production of domestic hot water and winter and summer air conditioning.
- **Electric Renewable**: The electrical output of systems powered by renewable sources, which must be mandatorily installed on or within the building or its appurtenances, measured in kW, is calculated according to the following formula:

$$P = K \cdot S$$

Where:
K is equal to 0.025 for existing buildings and 0.05 for new buildings;
S is the floor area of the building at ground level or the ground projection of the building outline, measured in m².

The innovative side of this decree lies in raising the minimum legal percentage for **renewable coverage of primary energy**, incentivizing the use of renewable sources. Raising the renewable coverage ceiling for building heating, cooling and DHW production is thus intended **to push in the implementation of renewable energy production systems** for newly constructed buildings (or major renovation).

Since a limit such as 60% represents a rather high coverage percentage, this could have several implications for building and systems design. Suffice it to say that for certain buildings (e.g., skyscrapers) with limited roof dimensions, it may be necessary to extend PV to the façade s as well. A second possible positive implication of the Decree is the use of more **combined systems** to further increase production. Thus, heat pump systems (water, principal, or geothermal systems) and photovoltaic panels, or even biomass generators, will be used for generation.

The next table (extracted from D.M. 26/06/2015) shows the different types of energy carriers and their conversion coefficients to renewable and nonrenewable primary energy for building performance calculation.

Energy Carrier	$f_{P,nren}$	$f_{P,ren}$	$f_{P,tot}$
Natural Gas	1.05	0	1.05
LPG	1.05	0	1.05
Diesel and fuel oil	1.07	0	1.07
Coal	1.10	0	1.10
Solid Biomass	0.20	0.80	1.00
Liquid/gaseous biomass	0.40	0.60	1.00
Grid Electricity	1.95	0.47	2.42
District Heating	1.5	0	1.5
Urban solid waste	0.2	0.2	0.4
District Cooling	0.5	0	0.5
Thermal energy from solar collectors	0	1.00	1.00
Electricity generated by photovoltaics, mini-wind and mini-hydro	0	1.00	1.00
Thermal energy from the external environment - free cooling	0	1.00	1.00
Thermal energy from the external environment – heat pumps	0	1.00	1.00

The second column highlights the conversion factor to renewable primary which is used for the calculation, as seen above, of compliance according to the Minimum Requirements. Thus, it is evident that **solid biomass together with thermal energy from solar collectors, photovoltaics and wind power** contribute more to the achievement of the targets and therefore bring more advantages under the point of renewable coverage.

However, certain **types of buildings are exempt** from the obligation, such as those connected to a district heating/cooling network (if such a system covers the entire thermal energy demand), temporary buildings (to be removed within 24 days of completion of work), and listed buildings (if compliance also implies incompatible alteration

5.2.1.3 National Incentives

In addition to government regulations in this filed, several incentives have been promoted in recent years in Italy to boost energy performance and renewable energy among private and public buildings.

A noteworthy incentive is surely the **Superbonus 110**. Superbonus is generally defined as the 110% tax deduction recognized by law for certain types of expenses incurred for interventions on homes, according to Article 119 ("Incentives for energy efficiency, Seismic Bonus, Photovoltaics and Electric Vehicle charging stations") of Decree Law No. 34 of May 19th, 2020 "Relaunch Decree" ("Decreto Rilancio"), with amendments by Law 77 of July 17, 2020, that regulates the scope of the incentive.

The bonus is a facility of an extraordinary nature aimed at supporting in favorable manner certain types of expenses incurred essentially to upgrade existing buildings both from an energy point of view and for the prevention of seismic risk; two areas in which it is evidently intended to invest in order to take advantage, at the level of the country system.

Superbonus incentive can be defined the sum (raised at 110%) of the deduction already provided for two types of intervention:

- **Ecobonus** (50% or 65% deduction depending on the type of work);
- Sismabonus (70% or 80% deduction raised to 75% or 85% for common parts of multifamily buildings).

Practically, the Superbonus covers different types of interventions, which can be "drivers" (and therefore mandatory to obtain the incentive) or "driven". The replacement of existing winter air conditioning systems with central heating and/or cooling and/or DHW, condensing or heat pump systems or thermal insulation interventions of opaque surfaces affecting the building envelope are "driver" interventions, while expenses for photovoltaic systems or the installation of charging stations for electric vehicles are called "driven" interventions.

Censis (Center for Social Investment Studies) estimated that the €55 billion of investments certified by Enea (National Agency for New Technologies, Energy and Sustainable Economic Development) for the period between August 2020 and October 2022, related to the use of the Superbonus, activated a value of production in the construction and related technical services supply chain of €79.7 billion (direct effect), plus €36 billion of production activated in other sectors of the economic system related to the components of the induced activity (indirect effect), for a total of at least €115 billion. Seeing these numbers, it is possible to estimate numerous benefits associated with the introduction of this incentive. Certainly, beneficial fiscal and employment effects, but the main question surely is inherent in the **effects in terms of energy efficiency and environmental sustainability.**

Censis estimates that, based on available data, spending 55 billion euros generates savings of 11,700 Gwh/year, which corresponds to 1.1 billion cubic meters of gas, equal to 40% of the energy savings that the Emergency Plan for Reducing Consumption in the Domestic Sector aims to achieve in autumn-winter 2022-2023 (2.7 billion cubic meters of gas). The reduction in CO_2 emissions due to interventions with the superbonus can be estimated at 1.4 billion tons of lost emissions, which contribute to the reduction of the ecological footprint of Italy's building stock and make it possible to achieve important results in the country's ecological transition process.

On the other hand, there are different actors who recognise the onerousness and complexity of this measure, not allocating funds in the most efficient way. Banca d'Italia (Bank of Italy) in a study issued in October 2022 [92]noted that the cost of the measure is relevant and by analysing the "Social Cost of Carbon" the Superbonus is not providing economic return before many decades apart for some very limited cases, while other investment of national infrastructures would be more efficient.

Another National organization, ENEA, highlighted the higher cost for saved kWh respect to other, previous and simpler incentives[93]: Superbonus cost effectiveness ranges between 15-19 c€ for every saved kWh, while Ecobonus, the previous simpler incentive for energy efficiency, cost-effectiveness ranges between 8 c€/kWh and 18 c€/kWh, with similar figures but cheaper on the overall.

Another relevant incentive is the **Bonus Casa**, a Tax deduction of 50% for Homes' Renovations, aimed at building structures (reduction of transmittance of vertical/horizontal structures to unheated or outdoor spaces and windows and doors), technological systems (solar collectors, replacement of boilers, heat pumps, hybrid systems, district heating, storage systems, automation systems), home appliances (replacement with class A+).

The **Bonus Facciate** (Façade Bonus), promoted in 2021, was a major state incentive (with 90% tax deductions) aimed at the thermal envelope component. The incentive was initially intended at the upgrading of the existing building stock for Italian buildings located in parts of the territory affected by urban agglomerations of historical, artistic, or special environmental value and in general to totally or partially built-up parts of the territory.

From the point of view of energy efficiency, the incentive is of particular importance because of its function in upgrading the existing housing stock and raising the thermal performance of buildings built in past decades, which are often more disadvantaged.

In fact, in the case of facade refurbishment works that are also influential from a thermal point of view (e.g., façade thermal insulation) it is necessary to comply with specific requirements in order to benefit from the 90% deduction with the "Minimum Requirement" stipulated in the Decree of the Minister of Economic Development of June 26, 2015 (explained above).

The last incentive that needs to be mentioned, valid for both the public and private sectors, is the "**Conto Termico**" (Ministerial Decree 12/06/2016) for the encouragement of small-scale interventions to increase energy efficiency and thermal energy production from renewable sources according to principles of simplification, effectiveness, diversification and technological innovation as well as consistency with the objectives of energy upgrading of public administration buildings.

5.2.1.4 CAM: Minimum Environmental Criteria

So far, laws and incentives in the private building sector have been mentioned. As for the **public sector**, however, it is worth mentioning the **CAM** or Minimum Environmental Criteria (*Criteri Ambientali Minimi*). The application of minimum environmental criteria, applied in public procurements, enables **contracting stations to enhance the environmental and social quality** of the activities put out to tender, rationalize their consumption, and reduce related spending, setting stricter requirements respect to private developments.

CAM are adopted in the stage of **defining the bidding process** to select candidates (technical capacity to ensure the execution of the contract in total respect for the environment); technical specifications

[92] https://www.edilportale.com/news/2022/10/risparmio-energetico/superbonus-per-bankitalia-costa-troppo-e-l-aliquota-va-abbassata_90977_27.html

[93] https://www.efficienzaenergetica.enea.it/pubblicazioni/rapporto-annuale-detrazioni-fiscali/rapporto-annuale-detrazioni-fiscali-2021.html

of performance of the works, supplies or services; the award criteria (requirements aimed at selecting products/services with better environmental performance to which a technical score is to be attributed for the purpose of award according to the most economically advantageous tender); and contract clauses to provide indications to execute the award or supply in the best way from the environmental point of view.

CAM influences and regulates public procurement in various fields, for example: street furniture, construction, public lighting, municipal waste management, vehicles, public green, and so on. The CAMs that most influence the topic of this report are those related to **contracting energy services for buildings**, **heating/cooling service**, lighting and motive power service.

In the case of **energy-environmental upgrades**, interventions to reduce the environmental impacts of the service, and in particular the consumption of energy from nonrenewable sources, must mandatorily be identified. In particular, the project must evaluate:

- interventions for the reduction of electrical energy requirements in buildings (e.g., increasing the brightness of rooms, reducing direct sunlighting, etc),
- interventions for increasing the efficiency of appliances and systems;
- on-site use of renewable energy sources (photovoltaic panels, wind generators, etc),
- use of high-efficiency cogeneration plant powered by renewable sources that also provides thermal energy for space heating (renewable sources consisting of biomass or biogas must be produced in a short supply chain i.e. within a radius of 70 kilometers from the plant that uses them to produce electricity)

Energy Communities (*Comunità Energetiche)*

Energy Communities also deserve mention in this chapter. **Renewable energy communities** are associations formed by local public administrations, companies, businesses, and individual citizens. These public and private users voluntarily equip themselves with facilities to produce sustainable energy for self-consumption, through a model based on sharing the electricity produced. In this way, an exchange system is created, in which all connected users can share the energy produced and not consumed with other members of the energy community.

The operation of an energy community revolves around the **smart grid**, a connected and intelligent grid infrastructure to which all members of the renewable energy community are connected. The energy can be produced by collective or individual systems: in the former case, for example, it is a photovoltaic power plant financed by the entire community; in the latter case, it is photovoltaic solar panels installed on the roof of one's home.

Then each member of the community uses part of the energy produced through self-consumption, while the remaining energy not consumed is fed into the grid and sold to other members of the energy community. The smart grid can also include storage systems, i.e., batteries for storing electricity produced but not required by any member of the renewable energy community.

In terms of the economics, each member of the community continues to pay the bill to the electricity supplier but receives periodically from the community an amount due to the sharing of the economic benefits from both the sale of surplus energy and the incentives provided by the GSE Energy Services Operator (GSE), which are provided by law for shared energy.

Thanks to the latest legislative measures explained later, **Italy has also made significant progress** in the renewable energy community sector.

Compared to other European countries, Italy paid a regulatory delay. Today, however, to recover this gap the government have introduced new *ad hoc* regulations; therefore, renewable energy communities in Italy are regulated by:

- Article 42-bis of "**Decreto Milleproroghe**" 162/2019, converted by Law No. 8/2020 of February 28, 2020, through which renewable energy communities were recognized;
- related implementing measures such as ARERA's Resolution 318/2020/R/eel and MiSE's Ministerial Decree September 16, 2020;
- Legislative Decree 199/2021 implementing the **European RED II Directive** on the promotion of the use of energy from renewable sources, through which the European Union recognizes the legal value of associations and introduces the figure of the energy producer/consumer (prosumer).

Plants producing electricity from renewable sources must have a total capacity of no more than 1 MW to be included within an energy community, moreover they must be connected to the electricity grid through the same primary cabin dedicated to all members of the energy community.

Legambiente (an Italian nonprofit association working in the field of environmental sustainability) in its report Renewable Communities 2021 surveyed what energy communities are in Italy, identifying **20 renewable energy communities** throughout the country. In Italy, very different examples are recorded, some relevant examples follow.

In Naples precisely in the neighborhood of "San Giovanni a Teduccio", the first renewable and supportive energy community in Italy has been launched. The project involves 40 families with social hardship who will be included in a path of awareness an increased awareness of energy issues.

GECO, Green Energy Community is a European project located close to Bologna (Emilia-Romagna) coordinated by AESS (Agency for Energy and Sustainable Development) aimed at building a district energy community. The project was launched in 2019, with the first meetings with stakeholders and the organization of a national working table, which involved different actors of the energy system. After an initial analysis, which touched on legal, technological, economic and cultural aspects, GECO was effectively established, with citizen engagement activities. The panels were installed in 2021 and the consolidation phase will end this year. The planned PV power is 200 kW, which is combined with a storage system. The territory GECO is targeting includes 7,500 inhabitants and a commercial area of 200,000 square meters.

In any case, energy communities in Italy are not only focusing on photovoltaics. For example, the Pinerolo Energy Community (Turin, Piedmont) uses a mix of sources, including biogas generated from the treatment of organic waste with which they produce thermal energy and electricity. The latter is also provided by a hydroelectric power plant and a photovoltaic plant.

5.2.2 Regional Regulations

In Italy, for this type of subject matter, the state is reserved for establishing the general principles of legislation, while the **regions** are responsible for **detailed regulations**. This. consequently, adds another **degree of complexity** to the treatment of Italian energy efficiency and renewable energy regulations.

For example, the regions of Abruzzo, Basilicata, Calabria, Campania, Lazio, Marche, Molise, Puglia, Sardinia, Sicily, Tuscany, Umbria, and Veneto refer to the National Guidelines and, for Energy certifications, do not have a Roll of Accredited Professionals. The National Guidelines are those explained in the previous chapter.

The other regions (in **red** below), **Emilia Romagna, Friuli Venezia Giulia, Liguria, Lombardy, Piedmont, Valle d'Aosta**, and the provinces of **Trento and Bolzano**, on the other hand, have their own regional regulations dictated by Regional Decrees and have their own accreditation Rolls for Energy Certifiers.

The **Lombardy Region**, for example, implemented the Ministerial Decree 26/06/2015 (mentioned in the dedicated chapter), with **DDUO** (Decree of the Director of the Organizational Unit of the Regional Council) **6480/2015**, a new "single text" in force for the Region of Lombardy regarding the application of minimum energy performance requirements for different types of interventions on buildings and systems, the calculation method and the requirements of professionals qualified for energy certification. Subsequently, new decrees came to supplement the previous one, mentioned below only for knowledge: DDUO 176/2017, DDUO 2456/2017 and DDUO 18456/2019.

The Lombardy Region regulation, unlike the national text, introduces new conversion factors for primary energy of energy carriers. Primary energy, as mentioned earlier, is the index that is considered to determine the energy performance of buildings. In particular, **district heating based on municipal solid waste** incineration has for the Lombardy Region a conversion factor of non-renewable primary energy (fP,nren) that increases from 0.5 to 0.2 and of renewable primary energy (fP,ren) from 0 to 0.20.

It is possible to consider this a clear indication that the type of energy carrier has been widely used and implemented in Lombardy more than in the rest of the country and thus represents a viable alternative to the more common renewable systems. In addition, the inclusion of a renewable energy conversion index is also an incentive from the point of view of building energy certifications, since as renewable coverage increases by implementing this type of generation in projects.

Another important difference of the Lombardy Region from the national regulations concerns **Renewable Sources**. In fact, a requirement for on-site renewable energy production is introduced not only for newly constructed buildings, or major renovations, but also to buildings where changes are made to the thermal/electric power generation plant. This requirement, more stringent than the National one, thus broadens the scope of interventions and consequently the regional renewable energy envelope.

Along with Lombardy, as defined above, there are also **other Italian regions** whose regulations contain different elements than the national regulations. Many of these differences could be mentioned, however, to shorten the analysis, only the main and most stringent differences have been set out. It is emphasized that the following is not intended to be an exhaustive picture but to give an idea of the **complexity and fragmented nature of the Italian legislative framework** about energy efficiency and renewable energy.

Emilia Romagna region, for example, has mandatory centralized thermal systems for summer and winter air conditioning for public buildings or public use; alternative high-efficiency systems to be considered when designing new buildings or major renovations of existing buildings; and minimum allocations of charging infrastructure or provision for residential/non-residential buildings. In the **Piedmont Region**, however, only the energy requirements of the building system for heating and not cooling and Domestic Hot Water are verified.

5.2.3 Municipal Regulations: the case of Milan (Lombardy)

Within the Milan Land Use Plan (also called PGT), **Article 10 "Environmental Sustainability and Urban Resilience"** dictates provisions to promote and incentivize environmental sustainability and urban resilience through the introduction of new stringent standards, able to be an example for all other cities in Europe and all over the world. This standard applies to newly constructed private and public buildings, restoration works, conservative rehabilitation, building renovation, building renovation with total demolition and reconstruction within the city limits.

According to Art. 10, the calculations to be made are of two types.

1. Calculation of **CO2 emissions**.

Minimization of CO2e emissions by **15% for restoration, preservation and building renovation work**, compared to the emission values associated with the overall energy performance limits is mandatory. On the other side, for **new construction**, **urban renovation and building renovation with demolition and reconstruction**, the achievement of **carbon neutrality** is mandatory, finally including this requirement within construction industry.

The above performances might be achieved through the use, in alternative or combinated way, of the following design elements:

- high energy performance solutions;
- re-naturalization interventions, including through forms of green integrated into buildings;
- technologies for reduced water consumption and rainwater reuse;
- use of sustainable materials and/or recycled content;
- adoption of surface finishes with a high solar reflectance coefficient;
- solutions for sustainable mobility.

2. **Climate Impact Reduction (RIC)**

Without affecting minimum standards of permeable surface area defined by the Building Regulations, the implementation of interventions must include solutions to improve environmental quality and adaptive capacity through compliance with a "climate impact reduction" index, understood as the ratio of green surfaces to the territorial area of the intervention. This index can vary from 0.1 (10%) to 0.3 (30%) depending on the type of intervention.

Achieving this index can be done by incorporating one of the following solutions (alternative or combined) for the types of green surfaces:

- permeable ground surfaces, to be counted at 100% of their extent;
- greened semi-permeable ground surfaces, to be computed at 50% of their extent;
- paved semi-permeable ground surfaces, to be counted at 30% of their extent;
- green roofs architecturally integrated into buildings and equipped with drainage layer, to be counted at 70% of their extension;
- green roofs of underground structures equipped with a draining layer, to be counted at 50% of their extension;
- green walls architecturally integrated into buildings, to be counted at 30% of their extension.
- Existing land endowments are not counted in the calculation.

Importantly, the option is given **to monetize and compensate for interventions** if the regulatory benchmark cannot be achieved, and the compensation is directly related to CO2e emissions and permeable surfaces. As a result, developers are encouraged to invest in such performance in order not to pay extra to compensate for not achieving the target, as the additional expenditure can be game-changing in a competitive economic-plan, as for the majority of the private developments within the city.

The resources from the monetization will be used for the construction of the future metropolitan park as well as for the de-paving of areas outside the intervention lot.

5.3 Energy market rules and tariffs

5.3.1 Overview

In 2021, gross national production amounted to 289.1 TWh and registered an increase of 3.0% compared to 2020. Specifically, 59.0% of national production was covered by non-renewable thermoelectric production (+ 5.5% compared to 2020), 16.4% by hydropower (- 4.1% compared to 2020) and the remaining 24.6% by wind, geothermal, photovoltaic and bioenergy (wind + 11.5%, photovoltaic + 0.4%, geothermal -1.9% and bioenergy -2.9% compared to 2020).

Traditional fossil fuel decreased from 74% in 2005 to 51% in 2021. At the same time, renewable energies increased from about 14% to 36%. In particular, the growth of renewables has been driven since 2011 by wind and photovoltaics as shown in the graph below.

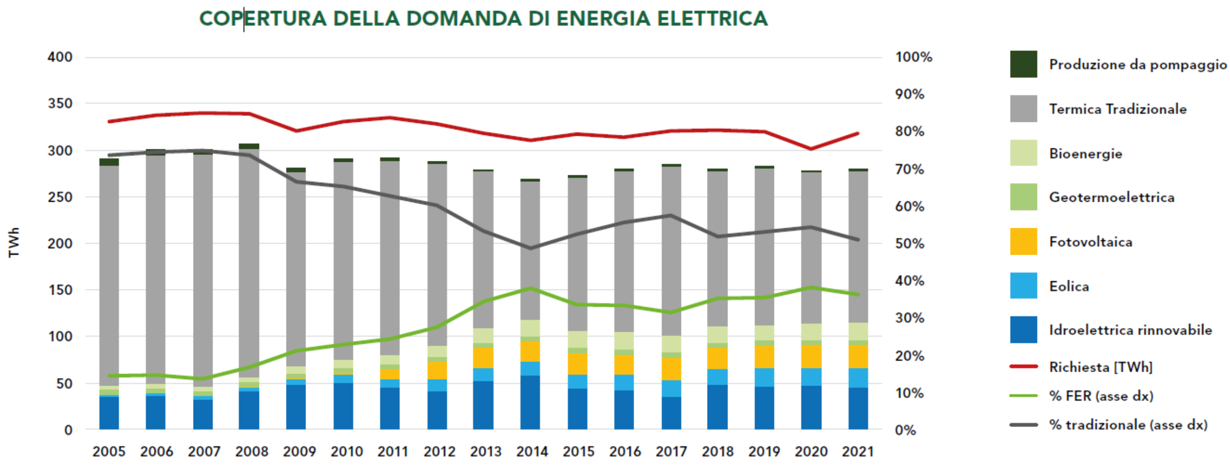


Figure 5-6: Production per source (GWh), Source: Terna

As in previous years, the focus of new installations in 2021 remains on photovoltaics, but the strongest growth was recorded in wind power, which increased by 150% (more than 400 MW in 2021 compared to 160 MW in 2020).

Bioenergy and geothermal remain unchanged compared to 2020 (4.8 GW in total). The increase in installed capacity in hydropower plants is small (11 MW added) and confirms the stable trend that has characterised hydropower for several years. The following figure shows the different distribution of renewable energies in Italy.

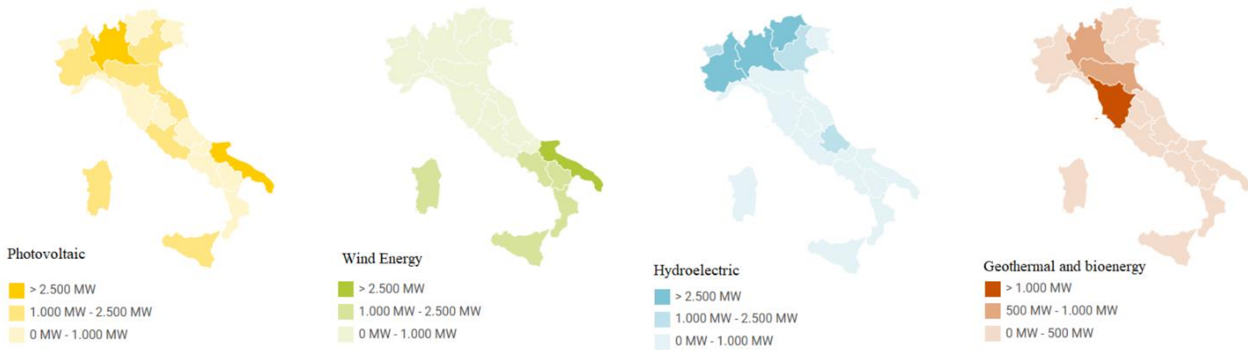


Figure 5-7: Renewable energies distribution (2022) (Source: Terna)

5.3.2 Electricity market

To understand how the market is work and to analyse recent trends, the mechanism is detailed described below.

In general, the Italian Electricity Market was created by Legislative Decree No. 79 of 16 March 1999 (D.Lgs. 79/99), which transposed the European Directive on the internal electricity market (96/92/EC) into national law.

The creation of an electricity market in Italy was intended to promote competition in the production, sale, and purchase of electricity in an environment regulated by the authorities and to ensure the economic management of an adequate supply of ancillary services.

The market is open to all eligible customers (i.e., natural, or legal persons who purchase electricity not for domestic use), including producers and wholesale customers.

The Italian Electricity Market consists of the Spot Electricity Market (MPE) and of the Forward Electricity Market (MTE) as depicted below.

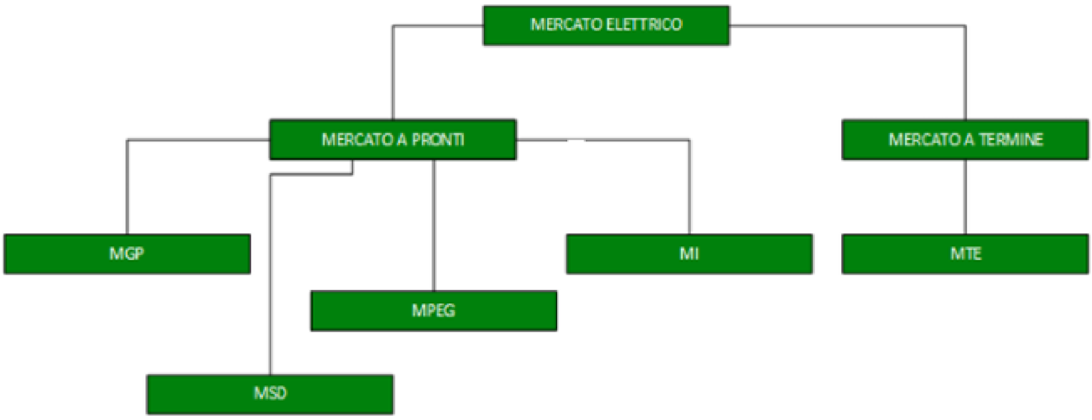


Figure 5-8: Italian energy market Source: GME

Focusing on the Spot Electricity Market:

- Day-Ahead Market - DAM (energy market) is an auction market and hosts most of the electricity sale and purchase transactions and it is considered the main market. In this market, participants submit offers and requests in which they specify the quantity and price at which they are willing to sell and buy and define the hourly blocks of energy for the following day. The criterion for accepting bids and requests is based on the order of economic merit of the technologies, considering the transmission capacity limits of the National Grid. Bid (producer) prices are defined hour by hour according to the intersection of the demand and supply curve and are differentiated from zone to zone when transmission capacity limits are saturated. Demand offers (buyers) are priced at the "Single National Price" ("Prezzo Unico Nazionale" - PUN), the average of the prices of the geographical zones, weighted by the quantities purchased in those zones.
- Intra-Day Market - MI (energy market) allows market participants to modify the timetables defined in the MGP by submitting supply offers or additional demand offers. The sale and purchase mechanisms are the same as in the PGM, however, but accepted buy offers are priced at the so-called zonal price.
- Daily Products Market – MPEG (energy market) is the trading venue for daily products with an energy delivery obligation. All participants of the electricity market are automatically admitted to MPEG. Trading on the MPEG takes place continuously and allows daily products to be traded at the 'differential unit price', i.e., the differential from the PUN, at which Participants are willing to trade these products, or the 'full unit price', that is the expression of the unit trading value of the electricity traded.
- Ancillary Services Market- MSD is where Terna S.p.A. procures the resources it needs for system management and monitoring, intra-zonal congestion elimination, the creation of energy reserves, and real-time balancing. In the MSD, accepted offers are remunerated at the price offered (pay-as-bid).

To conclude there is the forward Electricity Market (MTE), which is the place for trading energy futures contracts with delivery and withdrawal obligations. It is a market where trading takes place on a continuous basis. Traders submit their bids, specifying the number, type and delivery period of the contracts and the price at which they are willing to buy and sell. All electricity market participants can take part in the futures market.

5.3.3 Single National Price (PUN)

In more detail below, we will analyse the structure of the single national price (PUN - Prezzo Unico Nazionale).

The PUN is the wholesale reference price of electricity purchased on the market of the Italian Power Exchange. The PUN represents the national weighted average of the zonal sales prices of electricity for each hour and for each day. The national figure is an amount which is calculated on the average of several factors, and which considers the quantities and prices formed in the different zones of Italy and at different times of the day.

The wholesale price of electricity is set directly in the market based on purchases and sales between the various actors involved, i.e., between producers and energy suppliers (who buy energy from producers to supply to their end customers).

Fluctuations in the PUN are a determining factor in calculating the final cost of energy in the bill. Energy suppliers generally have fixed-cost or indexed-cost tariffs for the end consumer regarding the price of the energy component. Opting for an indexed energy component price means that it will vary over time depending on the trend of the PUN on the Italian Power Exchange. An offer with a fixed energy component price, on the other hand, will remain unchanged for a certain period depending on the offer chosen, generally for one or two years.

In Italy and most European countries, the production of plants with lower generation costs (such as renewables) is not sufficient to cover electricity demand. For this reason, the price of electricity is often determined by plants with traditional sources.

As long as gas plants are the marginal technology at most times, the price of electricity can only be strongly influenced by the price of gas itself. With greater penetration of renewables in the national mix, the price can be more frequently determined by these sources and energy prices can benefit.

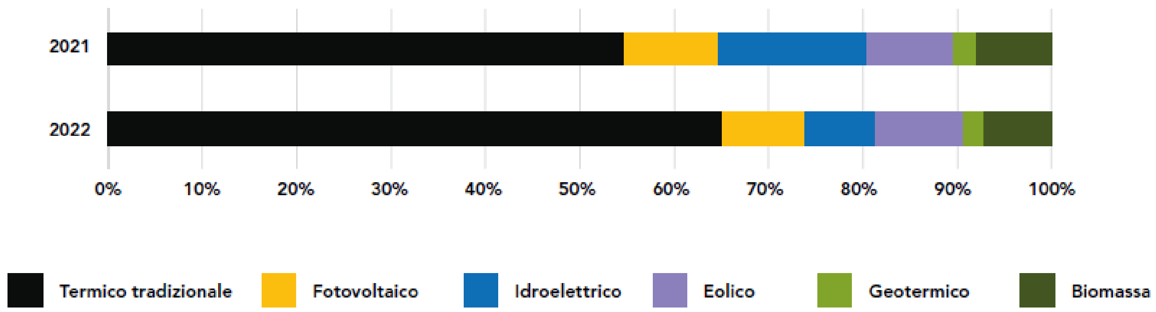


Figure 5-9: Demand coverage by source Sorce: Energy & Strategy group School of Management, Politecnico di Milano

For this reason, and given recent events, the price at which electricity was traded on the MGP rose steadily, from an average monthly value of €60.71/MWh in January 21 to an average monthly value of €281.24/MWh in December 21. During 2022 the price has continued to increase to reach

€543/MWh in August. This dynamic, which characterised all the main European power exchanges, is attributable to the steady increase in wholesale prices of natural gas and CO2 observed during 2021.

5.3.4 Final Energy Market

Legislative Decree No. 199 created common rules for the EU internal energy market. In Italy, there are essentially four divisions for the sale of electricity to final customers, the most important being the "protected market" ("Mercato di Maggior Tutela") and the "free market".

The main differences between the two markets are that in the free-market customers are "free" to choose their supplier and each supplier sets a price based on demand and supply on the "electricity exchange" where energy is bought and sold "wholesale".

Let us focus on the "protection market".

In 2021, domestic consumers and micro-enterprises served at low voltage and with a committed power of less than 15 kW who had not yet signed a contract of sale in the free market benefited from the Protection Service, which is guaranteed by specific sales companies or by distribution companies with less than 100,000 users connected to their network, based on economic and commercial quality conditions indicated by the Authority.

In the Protection Market, the final price of electricity is characterized by the following components:

1. Component linked to the committed power (€/kW) and is differentiated according to the voltage level to which each customer is connected (low voltage; medium voltage; high and very high voltage) and the intended use.

2. Fixed component €/customer/year (small and often negligible compared to the overall cost).

3. Component linked to actual consumption (€/kWh) and is basically made up of the following elements:

    - The tariff for the sales service
    - The tariff for the transmission service
    - The tariff for the distribution and metering service)
    - The tariff for the dispatching service
    - The tariff components linked to transmission surcharges
    - The Treasury taxes
    - Statutory VA

Over the last two years, the effects of the pandemic have impacted supply conditions in the Protection Service for a resident domestic consumer with annual consumption of 2.700kWh and power of 3kW (typical consumer). This first caused a multi-year low in the second half of 2020, and then the gradual recovery over the next twelve months caused a gradual climb back to pre-pandemic levels. Despite significant containment measures implemented by the Government and the Authority, the increases became increasingly strong after mid-2021, resulting in a value that more than doubled at the start of 2022.

The overall dynamic results from the evolution of the individual components, which are described below:

- the energy material, whose evolution is linked to the conditions of the wholesale markets, being the item with the greatest incidence, conditions the trend of the total price,
- transmission and metering costs remained substantially stable throughout the period around the average value of c€4/kWh, except for a slight reduction at the beginning of 2022,
- system charges at first had an average value close to c€/4.18kWh, then, after mid-2021, they were subject to government interventions that apported a significative reduction in the third quarter of 2021 and then to zeroing starting from the following quarter.

The fees covering electricity procurement and marketing costs in the first quarter of 2022 have an incidence of 80.8%, almost doubled compared to a year earlier (46.1%). These fees include the following items:

- energy purchase costs on the wholesale market,
- dispatching costs,
- the balances resulting from the equalisation system for electricity purchase and dispatching costs for customers with greater protection status,
- the items related to marketing.

Transmission and metering costs account for 10.8% of total gross price, an incidence almost halved compared to the beginning of 2021 (20%).

Starting from 2022, the general system charges (which twelve months earlier accounted for about 21% of the total price) have been reduced to zero as a result of the measures adopted by the government and the Authority to partially neutralise the effects of the sharp increases in the raw material component and thus contain the increase in the final price.

Moving on the free market, this represents 52.1% of final customers, and consequently, the market for major protection (where the price is periodically determined by the Public Decider) reaches 47.7% of final customer.

According to the data from the Annual Survey on the Regulated Sectors, 216.5TWh will be sold in the free electricity market in 2021, 14TWh more than in 2020, to just over 22 million customers, up by 6.9% compared to 2020.

Since its opening in 2007, the number of customers on the free market has increased steadily and significantly, as has the energy it has brokered and the number of sellers operating in it. In terms of energy sold, the free market has grown by 15%, from an initial 182TWh to the current 216.5TWh, although this expansion has taken place at a pace that has not always been sustained and, indeed, has also experienced some setbacks over the fourteen years. 2021 was a year of expansion, both in terms of electricity sales and the number of customers served.

However, regardless of the trend in quantities sold the number of sellers active on this market has been growing uninterruptedly since 2007, or rather, every year there is an increase in the number of companies with sales of less than 1TWh, although their market share is more or less stable around 5%. Free market is definitively a totally expanding reality.

The panorama of commercial offers available on the free market represents a very complex and varied reality, to which PLACET offers have been added for some years. Every free-market vendor is in fact obliged to include in its menu of commercial offers, for the benefit of small customers, two PLACET offer formulas - one at a fixed price and one at a variable price - characterised by general supply conditions established by the Authority except for the price, the level of which is freely defined by the vendor.

Regarding the type of preferred price, it was found that 81.4% of domestic customers subscribed to a fixed price contract on the free market (the price not changing for at least one year from the moment of subscription), while 18.6% chose a variable price contract, (the price changing according to the times and methods established by the contract itself). Variable price contracts are more widespread among non-domestic customers: 54.9% of them chose the variable price, while the fixed price contract was chosen by 45.1% of non-domestic points.

6 Appendix F: Poland

6.1 Cultural, economic, and social aspects

Case studies (D4.2) experiences on implementation of IES in the co-design process led to the following conclusions:

Generally, while often substantial, finance and technology-related challenges are often solvable, but require early-on involvement/inclusion of relevant (external) expertise for coherent, integrated planning. Moreover, building specific IES solutions in multi-stakeholder contexts are relatively easy to implement as the building context and preferred solutions are generally homogenous. Instead, when considering IES solutions for a more heterogenous real-estate building portfolio, more heterogenous technology packages and finance solutions are required, which can easily lead to a quickly growing information and data intensity, and the whole process is more complicated. Therefore, especially in such cases, the co-design service is highly required.

In terms of participatory opportunities, the case studies explored, with stakeholders, the benefits of collaboration between buildings and their owners. In the Polish multifamily buildings and the primary school and kindergarten cases, the option of establishing energy cooperatives has been highlighted as a solution to supply renovated settlements of buildings with RES from PV farms and use of building-level heat pumps. Currently, however, there are no examples of developed and operating energy cooperatives. Finally, it has been found that stakeholders in general are (increasingly) aware of the benefits of energy system improvement and several case studies also experienced that building management has been receptive to suggested improvements, to be even carried out in the short term, albeit not all directly related to IES.

Case studies have shown that this co-design approach requires building trust from both sides (end-users and co-design service providers). Building mutual trust is a time-consuming process, it requires many contacts, meetings, workshops on new technologies, variant analysis, organization of the investment process and finally reaching a consensus, also on the costs of the project and the possibilities of obtaining financial support. The co-design service meets these requirements but as mentioned before, it is not common and requires wide promotion and dissemination.

In general, decisions regarding energy transitions bind investors for many years. Thus, apart from the one-off investment costs, the operating costs, which are influenced by energy carriers, are also important.

The stability of the national energy policy, which is a strong facilitating factor, has a significant impact on both types of above-mentioned costs. In Poland, changes in energy policies, especially in phasing out fossil fuels, have destabilised markets for investors, technology, and material suppliers. For instance, the introduction of the prosumer net-metering scheme in Poland enabled phasing-out fossil-fuelled boilers in semi-urban areas and in the countryside, leading to a growing interest among end-users of all sectors, including from the supply side to deliver IES. However, since April 2022 the prosumer scheme has been downgraded from net-metering to net-billing, and that has reduced the feasibility of IES for residential customers.

Additionally, the war in Ukraine has made energy transition decisions even more difficult.

The renewable energy and thermal modernization markets have changed due to rising prices of labour, building materials, PV technology and heat pumps. Heat pumps prices are now rising by around 10% each month [94]. In 2021, the cost of square meter of house insulation - replacement of windows, ceilings, doors, wall insulation - was about 100 PLN. In July 2022, these costs are two or even four times higher. This situation will lead to increased energy poverty.

The case studies analyses carried out as part of the RES4BUILD project included building located in non-urban areas, where district heating network is not available, and the multi-family buildings are heated from a local, private coal-fired boiler house. The buildings are inhabited by people with lower incomes (compared to cities), therefore the final investment decisions depend on the possibility of obtaining funding.

Even before the increase in energy prices, every tenth household in Poland suffered from energy poverty - caused by high costs and low incomes[95]. Other analyses speak of energy poverty at the level of 12% at that time.

From August 2022, it is possible to apply for the so-called 'carbon allowance' in the amount of 3,000 PLN (630 EUR), which covers the cost of purchasing approx. 1 ton of coal. It is estimated that heating an uninsulated 100 m^2 house requires about five tons of coal, and an insulated one - about three tons. The decision to pay out carbon allowance will certainly slow down the process of replacing coal with other energy carriers that began a few years ago. The data of the Central Emission Registry shows that out of almost 7.5 million declarations concerning heat sources in houses in Poland, more than 3.7 million households are heated with coal. These data are not complete as the obligation to submit declarations was introduced only in 2021 with the declaration deadline by mid-2022[96]. However, data by regions are not available.

Moreover, high inflation currently places investors in a difficult decision-making position, especially when it comes to repayable financing instruments. Further development of IES depends on clearly defined priorities for energy transition, prices stability in labour and supply market as well as legal solutions facilitating implementation of investments.

In conclusion, procedures aimed at helping social groups suffering from energy poverty should be implemented. Activities aimed at thermal modernization of residential buildings and ensuring effective and ecological access to heat should be particularly supported. As highlighted in the D4.2 report financial incentives should better focus on supporting both areas (IES and retrofitting).

Co-design services could support this system and become an element of one-stop-shops. Unfortunately, as of today, such a service practically does not exist in Poland. Therefore, it is highly recommended to create one-stop-shops to facilitate finding comprehensive information, energy consultation and receiving substantive and organizational support for energy efficiency and IES projects basing on co-design service.

6.2 Building codes and regulations

6.2.1 Regulations and policies aimed at improving the energy efficiency of buildings

1. **Law on Energy Performance of Buildings, together with implementing acts**

[94] https://www.gramwzielone.pl/dom-energooszczedny/108288/ceny-pomp-ciepla-coraz-wyzsze-taniej-nie-bedzie
[95] https://www.rp.pl/spoleczenstwo/art36764371-raport-o-ubostwie-energetycznym-czesci-polakow-nie-stac-na-ogrzanie-lokum
[96] https://www.gunb.gov.pl/strona/statystyki

The system for assessing and improving the energy efficiency of buildings operates under the based on the provisions of the ***Law on Energy Performance of Buildings*** and its implementing acts. The purpose of the Law on the Energy Performance of Buildings is to introduce solutions to improve the energy performance of buildings, including the implementation and dissemination of a system for assessing the energy performance of buildings.

The October 2022 amendment to the law implemented the provisions of Directive 2010/31/EU regarding:

- a long-term strategy for the renovation of buildings
- making available for statistical and research purposes, as well as to the building owner, at least aggregated, anonymized data on energy performance certificates,
- equipping non-residential buildings with automation and control systems,
- reviews of heating and air conditioning systems.

2. **Renewable Energy Sources Act**

The basic tool for promoting the use of renewable energy sources is the ***Law on Renewable Energy Sources***. The purpose of this law is to develop renewable energy in Poland in a sustainable way, by adjusting the ways of financing individual renewable energy source (RES) technologies and stabilizing them over a 15-year period. The Law on Renewable Energy Sources contains comprehensive solutions to organize the support system for renewable energy sources, consisting of in:

- maintaining the support system for existing RES installations, which will guarantee respect for vested rights for all those who were RES electricity generators before the law entered into force;
- to introduce new opportunities for existing renewable energy installations, in order to optimize the economic calculus (dedicated auctions);
- implementation of a modern auction system for new and modernized RES installations.

3. **Regulation on the technical conditions to be met by buildings and their location**

Issues related to the technical equipment of the building, energy conservation and thermal insulation, with respect to buildings being designed, constructed and subject to reconstruction or change of use, are regulated by the ***Regulation on technical conditions to which buildings and their location should conform***.

Minimum requirements for the energy efficiency of buildings that are being designed or constructed are specified in the Regulation on technical conditions to which buildings and their location should conform – the so-called WT regulation. The minimum requirements were formulated by specifying the permissible parameters related to energy demand. The calculated value of the index determining the annual demand for non-renewable primary energy (EP) for heating, ventilation, cooling and preparation of domestic hot water, and in the case of a public, collective residence, production, business and storage building - also for built-in lighting, should be less than the limit value specified in the WT regulation.

Building type	Partial EP values for heating, ventilation and domestic hot water as of December 31, 2020. [EP_{H+W} [kWh(m^2 · year)]
Residential building:	
a) single-family	70
b) multi-family	65
Residential building	75
Public utility building:	
a) health care	190
b) other	45
Commercial, storage and production building	70

The following table indicates EP ratios for building cooling needs

Building type	Partial EP values for cooling needs ΔEPC [kWh(m^2 · year)] as of December 31, 2020
Residential building:	
a) single-family	ΔEPC= 5 · Af,C/ Af
b) multi-family	
Residential building	ΔEPC= 25 · Af,C/ Af
Public utility building:	
a) health care	
b) other	
Commercial, storage and production building	

Af - area of rooms with controlled air temperature (heated or cooled), determined in accordance with the regulations issued under Article 15 of the Law of August 29, 2014 on energy performance buildings [m2],

Af,C- - area of rooms with controlled air temperature (cooled), determined in accordance with the aforementioned regulations [m2].

Definition of near-zero energy consumption building

At the national level, according to the Resolution [16], a "near-zero energy consumption building" is equated and referred to as a "low energy consumption building." A "low-energy consumption building" is considered to be a building that meets the requirements for energy savings for heating, ventilation, cooling and lighting [3] and thermal insulation (Appendix 2 of the Resolution [3]).

4. Regulation on the detailed scope and form of the construction project

Also, the ***Regulation on the detailed scope and form of the construction project*** contains requirements relating to energy performance and the possibility of using efficient alternative energy and heat supply systems. analysis of the rational use of highly efficient alternative energy supply systems.

According to paragraph 20 of the Regulation, the technical description of the architectural and building design of a building should include an analysis of the technical, environmental and economic feasibility of highly efficient alternative energy and heat supply systems, including decentralized energy supply systems based on renewable energy, cogeneration, district or block heating or cooling, especially when based entirely or partially on energy from renewable energy sources, and heat pumps. If the building:

- is not technically suitable for it,
- the environment is not conducive to the establishment or use of these systems,
- due to the cheaper operation of energy from other sources, it is not worthwhile to create them,
- then the analysis does not need to be carried out. However, if it is possible, and the analysis is not carried out, the project will not receive a building permit.

The analysis of the rational use of highly efficient alternative energy systems should include:

- Annual demand for usable energy for heating, ventilation, hot water preparation and cooling calculated in accordance with the regulations on the methodology of calculating the energy performance of buildings,
- Available energy carriers,
- Conditions for connection to external networks,
- Selection of two energy supply systems for comparative analysis:
- a conventional system and an alternative system or
- a conventional system and a hybrid system, understood as a combination of a conventional and an alternative system,
- Optimization-comparison calculations for the selected energy supply systems,
- Results of the comparative analysis and selection of the energy supply system

5. **Regulation on the methodology of determining the energy performance of a building or part of a building and energy performance certificates**

On April 18, 2015, the provisions of the Regulation on the Methodology for Determining the Energy Performance of a Building or Part of a Building and Energy Performance Certificates, issued on the basis of Article 15 of the Law on the Energy Performance of Buildings, came into force.

The ordinance regulates the method of determining energy performance, including by a method based on the amount of energy actually consumed, calculations of carbon dioxide (CO2) emissions and the share of renewable energy sources in annual final energy demand, as well as a model energy performance certificate. In addition, it was indicated that the energy performance certificate's fiche should include recommendations for cost-effective and technically feasible measures to improve energy performance

6. **Act on support for thermomodernization and renovation and on central register of building emissions**

Another piece of legislation closely related to improving the energy performance of buildings is the Law on Support for Thermomodernization and Renovation and the Central Record of Building Emission, under which the Thermomodernization and Renovation Fund was established.

The purpose of the Thermomodernization and Renovation Fund is to improve the technical condition of existing residential buildings, collective housing, and buildings owned by local government units for the performance of their public tasks. The program contributes to the reduction of annual energy demand, the reduction of annual energy losses, the reduction of annual heat acquisition costs and the conversion of non-renewable energy sources to renewable sources or the use of high-efficiency cogeneration.

Beneficiaries of this program include owners of housing stock (municipalities, housing cooperatives, owners of company housing and private owners), owners of collective housing, and local government units.

Based on the provisions of the law, the Central Record of Building Emissions (here) is in operation. It is an IT tool for the inventory of heat sources and fuel combustion sources in buildings.

The system collects key information on emission sources in the residential sector.

7. National plans and strategies to support energy efficiency improvements in buildings

The national plan to increase the number of low-energy buildings, was adopted by the Council of Ministers by resolution on June 22, 2015.

The national plan includes, in particular: the definition of low-energy buildings and their specific features, government actions taken to promote low-energy buildings, including the design, construction and reconstruction of buildings in an energy-efficient manner, and increasing the share of renewable energy in new and existing buildings. A timetable for achieving these goals is also included, which corresponds to Article 9(3) of the Directive.

The National Plan contains a lot of very important information and guidance for investors as well as designers and contractors. The National Plan discusses the main goal and intermediate goals related to improving the energy efficiency of buildings, along with a timetable for achieving them. It outlines the characteristics of activities, mainly by the government, undertaken to promote buildings with low energy consumption, including designing, constructing, and reconstructing buildings in an energy-efficient manner and increasing the share of renewable energy in new and existing buildings. In addition, the document discusses changes in regulations affecting the energy efficiency of buildings and identifies a number of financial mechanisms aimed at different groups of beneficiaries, such as housing communities, individuals, local government units, businesses and others.

The National Plan also raises the issues of promoting the use of renewable energy sources in buildings, the need to improve the technical condition of existing buildings and indicates aspects of a comprehensive approach to energy efficiency, with a view to meeting the main objective of pursuing the provisions of Article 9(1) of the Directive.

The content of the main provisions of the National Plan stipulates that:

- by December 31, 2020, all new buildings are near-zero energy buildings, and
- after December 31, 2018, new buildings occupied and owned by public authorities be near-zero energy buildings.

Another important government document relating to improving the energy efficiency of buildings is the ***Long-term Strategy for Renovating Buildings***.

The obligation to prepare the document stems from Article 2a of the Directive. The Long-Term Building Renovation Strategy is part of the Integrated National Energy and Climate Plan.

Among other things, the realization of the intended goal entails improving the energy performance of buildings, will have a positive impact on air quality by reducing greenhouse gas emissions into the atmosphere, and will have a positive impact on the generation of new jobs related to the performance of thermal rehabilitation of buildings.

The document defines the necessary measures to achieve high energy efficiency and low carbon performance of buildings in Poland in the 2050 perspective. Renovation of the building stock is one of Poland's biggest infrastructure challenges until 2050. As in other EU member states, Polish buildings in the long term should be modernized in a manner consistent with the transition to a climate-neutral economy. At the same time, national public policy must respond to the urgent need to replace the most emission-intensive heat sources in order to improve air quality, while ensuring that the value of buildings is improved.

The strategy is intended to "cost-effectively transform the national building stock into near-zero energy buildings."

For the purpose of developing the strategy, a review of all buildings in Poland, both public and private, was carried out, which showed that there are 14.2 million buildings, of which almost 40% are single-family dwellings. A significant portion of the buildings are characterized by low energy efficiency and will require thermal modernization in the coming years. The data shows a wide variation in the energy efficiency of buildings, both in terms of their purpose and the year they were put into use.

The strategy assumes an average annual rate of thermomodernization of about 3.8%, with the assumption that by 2050 65% of buildings will achieve an EP ratio of no more than 50 kWh/m2-yr.

Another document that takes into account energy efficiency issues in buildings is the one adopted by resolution by the Council of Ministers on October 20, 2015. "***National Urban Policy***". The strategic goal set forth in this document is to strengthen the capacity of cities and urbanized areas for sustainable development and job creation, and to improve the quality of life of residents, and improving energy efficiency in buildings is identified as one of the important tools for achieving this goal.

Reference should also be made to the ***Revitalization Law***, which introduces new solutions that allow, among other things, local governments to play a more active role in carrying out renovations and thermal upgrades in buildings. According to Article 9 of the law, the degradation of the technical condition of buildings identified in a certain area and the lack of functioning technical solutions for the effective use of these facilities, in particular with regard to energy efficiency, environmental protection and ensuring accessibility for persons with special needs, constitutes one of the premises for designating this area as a degraded area and including it in a municipal revitalization program.

Poland's Energy Policy until 2040 is 1 of 9 integrated strategies resulting from the "Strategy for Responsible Development" and is a strategic document, setting the directions of development of the fuel and energy sector. PEP2040 is a compass for businesses, local governments and citizens in the transformation of the Polish economy towards a low-carbon direction.

In 2040, more than half of the installed capacity will be zero-carbon sources. A special role in this process will be played by the implementation of offshore wind power and the launch of a nuclear power plant into the Polish electricity system. These will be two strategic new areas and industries that will be built in Poland. This is an opportunity for the development of domestic industry, the development of specialized human resource competencies, new jobs and the generation of added value for the national economy. Parallel to large-scale energy, distributed and civic energy - based on local capital - will develop.

The transition also requires increasing the use of RES technologies in heat generation and increasing the use of alternative fuels in transportation, including through the development of electromobility and hydrogen mobility.

Domestic coal resources will remain an important element of Poland's energy security, but the increase in demand will be met by sources other than conventional coal capacity. The share of coal in the structure of energy consumption will reach no more than 56% in 2030, and with increased prices for CO2 emission allowances it may even fall to 37.5%. Renewable sources will play an increasingly important role - their level in the structure of net domestic electricity consumption will be no less than 32% in 2030, which will enable primarily the development of photovoltaics and offshore wind farms, which, due to economic and technical conditions, have the greatest prospects for development. Natural gas will be a bridge fuel in the energy transition.

8. The F-Gas Act

The phasing out of HFC refrigerants is the main thrust of the Law of July 12, 2017 on Substances that Deplete the Ozone Layer and Certain Fluorinated Greenhouse Gases and Certain Other Laws. The national legislation has been aligned with EU law, with the overarching goal of counteracting the deepening of the greenhouse effect due to the emission of HFC refrigerants into the atmosphere. The tools to achieve this are to reduce the amount of these compounds in refrigeration, air conditioning and heat pump installations

6.2.2 Financial support measures for investments supporting the development of energy-efficient construction and the use of renewable energy sources

Poland is implementing comprehensive measures to support building renovation, which include legislative and organizational tools, as well as financial support from both domestic and EU funds. Programs such as Stop Smog, Clean Air, the Thermomodernization and Renovation Fund and European funds are key public programs aimed at gradually moving toward a climate-neutral economy.

The **National Fund for Environmental Protection and Water Management** (NFOŚiGW) is the main link in the Polish system for financing environmental protection and water management, including energy efficiency improvements in the construction sector. The NFOŚiGW operates on the basis of the Act of April 27, 2001. Environmental Protection Law [12]. Its main goal is to provide effective and efficient support for environmental activities with particular emphasis on activities to absorb foreign funds. The National Fund's revenues come mainly from environmental fees and penalties, operating and concession fees, energy sector fees, fees under the Law on Recycling of End-of-Life Vehicles, and from the sale of units of allocated greenhouse gas emissions, in accordance with the EU "polluter pays" principle.

1. *Czyste Powietrze*- Clean Air Program

In 2018. The National Environmental Protection and Water Management Fund and the provincial funds for environmental protection and water management launched the largest joint priority program “Clean Air” (**here**) in its history.

The main objective of the program is to improve air quality by reducing emissions of particulate matter and other pollutants into the atmosphere and improving energy efficiency and the use of renewable energy sources in single-family buildings, as well as enabling the widest possible local access to financial support for residents, including the elimination of energy poverty.

Under the program, it is possible to receive financial support for comprehensive measures related to the modernization of single-family residential buildings or separate residential units in these buildings with separate land registers. Support is provided for activities related to replacing heat sources, increasing energy efficiency and using RES in a single-family residential building, in particular by:

- replacing old-generation solid fuel heat sources (solid fuel furnaces and boilers), purchasing
- and installation of new heat sources, equipment and installations in particular: high-efficiency solid fuel boilers, heat substations, electric heating systems, oil boilers, condensing gas boilers, heat pumps,
- installation or modernization of central heating and hot water preparation systems,
- use of renewable energy sources (purchase and installation of micro photovoltaic systems, solar collectors),
- insulating the building envelope,
- replacement of window and door woodwork,
- purchase and installation of mechanical ventilation with heat recovery,
- preparation of documentation for the project, including, among others: energy audit of the building, branch project documentation, expert reports.

It is planned to allocate 103 billion zlotys over ten years for activities related to the program. It is assumed that about 3 million single-family homes will benefit and increase their energy efficiency, which in turn will significantly improve air quality in Poland. Subsidies

under the Clean Air Program can be combined with a thermo-modernization tax credit, effective from January 1, 2019, i.e. from the entry into force of the ***Act of November 9, 2018 amending the Act on Personal Income Tax and the Act on Lump Sum Income Tax on Certain Income Earned by Natural Persons***. In this case, the benefits received by the Beneficiary from both financial mechanisms are complementary.

2. ***Mój Prąd*- My Electricity**

Another flagship program currently underway is the "My Electricity" Priority Program (**here**) to subsidize the purchase and installation of photovoltaic panels by individuals.

The program is based on financing investments made exclusively by individuals to reduce the cost of energy demand in the residential sector in single-family buildings and individual dwellings with funds from the National Fund for Environmental Protection and Water Management.

The beneficiaries of the program are exclusively natural persons generating electricity for their own needs, who have a comprehensive agreement regulating the introduction of electricity generated in a micro-installation to the grid for residential purposes. According to the program, the installed system must be used for the household's own needs. The aim of the program is to increase the production of electricity from photovoltaic micro-installations in the Republic of Poland and reduce CO2 emissions.

The Program is being implemented starting in 2019. Under the Program, it is possible to obtain non-refundable support in the form of grants for projects involving the construction of a photovoltaic micro-installation with a capacity of 2 to 10 kW to meet the energy needs of residential buildings. The maximum amount of support is 50% of the eligible costs of building the microinstallation, but no more than PLN 5000 (in the 1st and 2nd call) or PLN 3000 (in the 3rd call). Support can be applied for by individuals who have a signed comprehensive agreement allowing the introduction of the produced energy into the grid. The condition for obtaining support is a commitment to operate the installation for at least 3 years from the date of payment of the subsidy.

Funding changes changed on April 1, 2022 and net-billing is now in effect. This is a new program that is less cost-effective than the previous discount system. As a result, the My Electricity 2022 program is not very popular.

Until now, prosumers have been billing the energy they consume and transfer to the grid on the basis of so-called net-metering, also known as the discount system or balance billing. Prosumers who did not use all the energy they produced would transfer; and surplus to the grid, where it could be stored for 365 days. For every 1 kWh transferred to the grid, a prosumer could collect:

- 0.8 kWh - for micro-installations whose capacity does not exceed 10kW,
- 0.7 kWh - for installations with a higher power output

Prosumer using net metering did not incur energy transmission costs (variable transmission fee). Thanks to this system, it was possible to compensate for the rising cost of energy purchases with savings resulting from the transfer of surpluses, and as a result reduce bills only to fixed charges or the excess of energy consumed over billed, if such a situation occurs.

In the new billing system - net billing, the value of energy given and taken will be billed, not the quantity as before. For this, the details of this billing are important. The selling price of energy injected into the grid is the monthly rate of the Market Energy Price. The value of consumed energy will be increased by a fixed transmission fee and a variable transmission fee. The transmitted energy, on the other hand, will be settled based on exchange rates from the energy of the so-called Day-Ahead Market (DAM). This means that the price at which energy will be purchased will be significantly higher than the price at which energy will be sold.

The ministry envisioned the changes to be implemented according to the following schedule:

- until June 30, 2022, all prosumers, including those connected to the grid after April 1, 2022, will settle on a net-metering basis
- from July 1, 2022 to June 30, 2024, prices for surplus energy settled on a net-metering basis are based on averages of the previous month's prices from the DAM
- from July 2024, prices for surplus energy settled on a net-billing basis are based on hourly prices from the DAM

The amendment also introduced the concept of a prosumer deposit, which means the value of funds owed to a prosumer for surplus energy transferred and can be used to purchase energy in case of a shortage. If the funds are not used for 12 months from the date of their assignment, the prosumer will be paid 20% of their value.

Among the reasons for the changes to the system are EU requirements - Directive 2019/944 of the European Parliament and of the Council (EU) of June 5, 2019 on common rules for the internal market in electricity and the RED II Directive.

Effects of the changes

The changes introduced do not involve new formal requirements or record-keeping obligations. However, the new system will affect the profitability of RES investments. The payback time on investments may be prolonged, but due to rising energy prices, obtaining energy from RES will still be profitable relative to standard and unfortunately rising electricity bills.

3. *Stop Smog*- Stop Smog Program

The goal of the program (**here**) is to reduce pollutant emissions and improve air quality and improve the energy efficiency of buildings through the implementation of low-emission projects for the benefit of the least affluent households in single-family residential buildings, including in particular those whose members are persons entitled to cash benefits under the Social Assistance Act of March 12, 2004.

The "Stop Smog" program supports thermal modernization, including replacement or elimination of heat sources, in single-family residential buildings. It is implemented by municipalities, but a party to the agreement on behalf of municipalities may also be a county, inter-municipal association or metropolitan association in the Silesian province.

The "Stop Smog" program is implemented on the basis of the Act of November 21, 2008 on Support for Thermal Modernization and Renovation and the Central Record of Emission of Buildings [13] and the Decree of the Minister of Climate and Environment of December 28, 2020 on the model statement of own funds and property resources of the person applying for a contract for the implementation of a low-carbon project.

The "Stop Smog" program is aimed at people affected by energy poverty living in single-family buildings. The program is addressed to all municipalities that can demonstrate poor air quality in their area. The program includes the implementation in the above households of projects consisting of:

- replacement or elimination of high-emission heat sources with low-emission ones
- thermo-modernization
- connection to a district heating or gas network
- providing buildings with access to energy from RES installations
- reducing the demand of single-family residential buildings for energy supplied for their heating and preparation of domestic hot water

Applicants in the "Stop Smog" program (municipality, inter-municipal association, county, metropolitan association in the Silesian voivodeship) can obtain up to 70% of the investment costs. The remaining 30% is their own contribution. As a result, residents of municipalities (located in areas where the so-called "anti-smog resolution" is in force) can receive up to 100% of the cost of the project in the form of a non-refundable grant. The average cost of low-emission investments in one building, or in the case of a building with two units - in one unit, may not exceed PLN 53 thousand.

4. *Fundusz Termomodernizacji i Remontów*- Thermomodernization and Renovation Fund

The rules for receiving funding from the Fund for Thermal Modernization and Renovation (FTiR) (**here**) are set forth in the ***Law on Support for Thermal Modernization and Renovation and the Central Emission Register for Buildings***.

The program for renovation and thermal modernization of residential buildings is aimed at improving the technical condition of the existing housing stock, especially the common parts of multi-family buildings. The primary objective is to provide financial assistance to Investors carrying out thermomodernization, renovation or repair of existing single-family residential buildings with the participation of loans taken from commercial banks. This assistance called respectively: "thermomodernization bonus," "renovation bonus," "compensation bonus," constitutes repayment of part of the loan taken out for the implementation of the project or renovation.

The budget of the FTiR is set every year, and its operation is continuous. FTiR is one of the of the oldest, continuously functioning, tools for promoting energy efficiency in Europe (it has been in continuous existence since 1998, having been established on the basis of the Act of December 18, 1998, on support for thermomodernization undertakings).

The system of support for the conduct of thermomodernization and renovation undertakings (renovation works related to thermomodernization) is financed from national funds and operates on the basis of the provisions of the Act of November 21, 2008 on support for thermomodernization and renovation and on the central register of building emissions. These regulations define the rules for granting thermomodernization bonuses, renovation bonuses and compensation bonuses. Bank Gospodarstwa Krajowego is responsible for their implementation.

From the beginning of FTiR's operation until December 31, 2021. FTiR was injected with PLN 2,873 million. The main beneficiaries of the FTiR funds were housing cooperatives and housing communities, which mainly subjected multifamily buildings to thermal modernization. The fund also includes support for municipal buildings included in the register of historical monuments or located in an area included in this register, but the premium for such buildings is 60% of the cost of the project.

The FTiR is administered by Bank Gospodarstwa Krajowego, which makes decisions on granting the bonus and, once the conditions for payment are met, transfers the bonus.

5. ***Ulga Termomodernizacyjna*- Thermal modernization tax credit**

The rules for the possibility of obtaining the thermomodernization tax credit are set forth in the Law on Personal Income Tax of July 26, 1991 and the Law on Lump Sum Income Tax on Certain Income Earned by Individuals of November 20, 1998. The thermal modernization tax credit is effective as of January 1, 2019. The thermal modernization tax credit is an instrument addressed to a wide group of taxpayers who own single-family buildings. The allowance is deducted in the tax return from income taxed according to the tax scale or income subject to the flat tax or income subject to the lump sum tax on registered income. The amount of the deduction cannot exceed PLN 53,000 for all thermal modernization projects carried out in buildings. The deduction cannot be used if the building is not put into use (it is under construction).

6. ***Program Ograniczenia Niskiej Emisji*- Low emission reduction program**

Low emission reduction programs (PONEs) are developed by municipalities in cases where air protection programs adopted at the provincial level through resolutions of provincial assemblies specify such an obligation. If the air protection program does not indicate an obligation for the municipality to develop PONEs, such action is voluntary. PONEs are prepared in municipalities where exceedances of permissible levels of PM10 and PM2.5 particulate matter and the target level of benzo(a)pyrene have been identified. The purpose of PONE is to reduce emissions of harmful substances and improve air quality. PONEs include measures to replace or eliminate old, inefficient heat sources.

		Building type					Directional activities				Period			
		Single-family	Multifamily	Public	Other non-residential	Historic or conservation building	Measures to improve air quality	Tackling energy poverty	Buildings with the worst energy performance	Countering conflicting incentives	2011-2014	2015-2020	2021-2025	2026-2030
Financial tools	Clean Air Program	x					x	x				x	x	x
	My Electricity Program	x					x						x	x
	Thermo modernization and Renovation Fund	x	x	x		x	x	x	x	x	x	x	x	x
	Thermal modernization tax credit	x					x					x	x	x
	Low Emission Reduction Programs	x						x	x			x	x	x
	Stop Smog Program	x						x	x			x	x	

Even though the share of single-family dwellings in the Polish building stock is much less than multi-family buildings, quantitative studies conducted in the country indicate that more than 80 percent of single-family buildings are heated with solid fuels (of which 3 million are "fossil fuels" that emit significant amounts of pollution). In turn, according to data from the National Center for Balancing and Managing Emissions, low emissions based on the combustion of solid fuels (mainly poor-quality coal and waste) in home heating systems are the source of many air pollutants, including PM2.5 PM10 and carcinogenic benzo(a)pyrene, among others.

The "My Electricity" program, which allows the installation of photovoltaic panels in single-family buildings, assumes, among other things, that all the electricity generated by a photovoltaic system in single-family buildings should be consumed by those buildings during the year. There is no program for the installation of photovoltaic installations in multifamily buildings. **The problem of installing these systems in multi-family buildings is that each apartment has a meter and each apartment is billed separately.** It is not possible to install a two-way meter in each apartment.

There is a power connection made to each multi-family building (and these are cooperative, community, company, municipal buildings), on which a two-way meter can be installed.

Currently, in the event that more than one collective prosumer of renewable energy generates electricity in a micro-installation or small-scale RES installation, they are obliged to conclude an agreement in which they specify, among other things: the share, expressed in percentage, of electricity generation from a renewable energy source to which each collective prosumer is entitled, the legal title to which the collective prosumers of renewable energy are entitled to the micro-installation or small-scale RES installation, and the prosumers' representative. A civil law agreement between collective prosumers has no legal personality, which means that it cannot itself be subject to rights and obligations.

In early 2021, the Climate Minister announced the start of work on a pilot program that will include funding for both heat source replacement in multifamily buildings and thermal upgrades. A **"Warm Dwelling" program has been created, which is aimed at owners and co-owners of single-family houses or detached dwellings in single-family buildings with a separate land register.**

On July 21, 2022, the call for applications for municipalities to make funds available under the Warm Housing program began. Municipalities can apply for funding under the program to the WFOŚIGW on a rolling basis, divided into two calls:

- the first is launched until 31.12.2022;
- while the second will be launched by 31.12.2023, depending on the availability of funds.

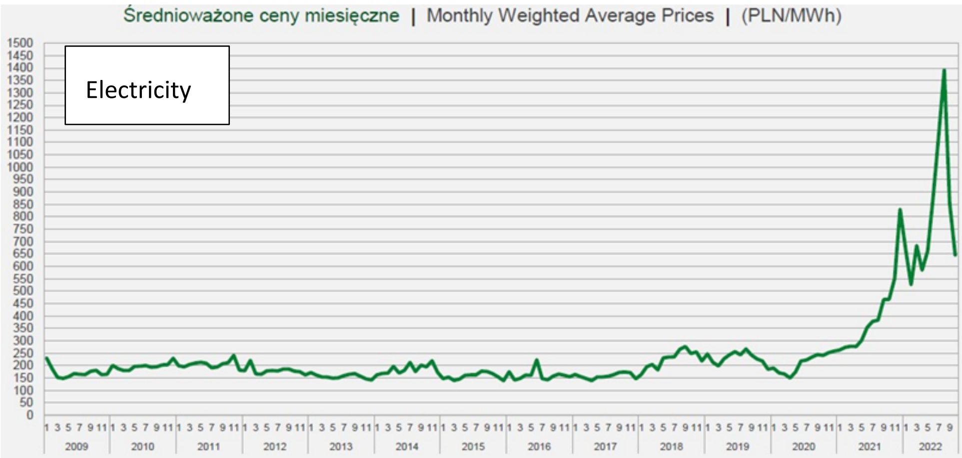
1. Act of 29 August 2014 on the energy performance of buildings
2. Act of 20 February 2015 on renewable energy sources
3. Regulation of the Minister of Infrastructure of 12 April 2002 on technical conditions to be met by buildings and their location
4. Regulation of the Minister of Transport, Construction and Maritime Economy of 25 April 2012 on the detailed scope and form of the construction design
5. Regulation of the Minister of Infrastructure and Development of 27 February 2015 on the methodology for determining energy performance of a building or part of a building and energy performance certificates
6. Act of 21 November 2008 on supporting thermal modernization and renovations and on the central register of building emissivity
7. Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings amended by Directive (EU) 2018/844 of the European Parliament and of the Council of 30 May 2018 amending Directive 2010/31/EU on the energy performance of buildings and Directive 2012/27/EU on energy efficiency and Regulation (EU) 2018/1999 of the European Parliament and of the Council of 11 December 2018 on the Governance of the Energy Union and Climate Action, amending Regulations (EC) No 663/2009 and (EC) No 715/2009 of the European Parliament and of the Council, Directives 94/22/EC, 98/70/EC, 2009/31/EC, 2009/73/EC, 2010/31/EU, 2012/27/EU and 2013/30/EU of the European Parliament and of the Council, Council Directives 2009/119/EC and (EU) 2015/652 and repealing Regulation (EU) No 525/2013 of the European Parliament and of the Council
8. Long-term building renovation strategy adopted by Resolution 23/2022 of the Council of Ministers of 9 February 2022
9. National Urban Policy. Document adopted by Resolution No. 198 of the Council of Ministers on 20 October 2015 (M.P. of 2015 r. item 1235)
10. Act of 9 October 2015 on revitalization
11. Regulation of the Minister of Climate and Environment of 28 December 2020 on the template of the declaration on own funds and property resources of the person submitting the

application for the conclusion of the contract for the implementation of a low-emission project

12. Act of 27 April 2001 on environmental protection law
13. Act of 9 November 2018 amending the Act on Personal Income Tax and the Act on flat-rate income tax on certain revenues earned by natural persons
14. Act of 20 November 1998 on flat-rate income tax on certain income earned by natural persons
15. Act of 26 July 1991 on personal income tax
16. Resolution No. 91 of the Council of Ministers of 22 June 2015 on the adoption of the "National plan to increase the number of low-energy buildings"
17. Act of 12 July 2017 amending the Act on substances that deplete ozone layer and on certain fluorinated greenhouse gases and certain other acts

6.3 Energy market rules and tariffs

The Polish energy and heating sectors are still based on coal, and as coal extraction in the country is declining, the market has become dependent on imports of this energy carrier, especially from Russia. Even before recent dramatic changes on energy markets Polish wholesale electricity prices were one of the highest in Europe, because of high coal and CO_2 emission allowance prices and low generation from renewables. So, nowadays, on the one hand, the availability of coal on the Polish market has decreased, and on the other - its price has quadrupled compared to 2020. At the same time, gas and electricity prices have risen as well.



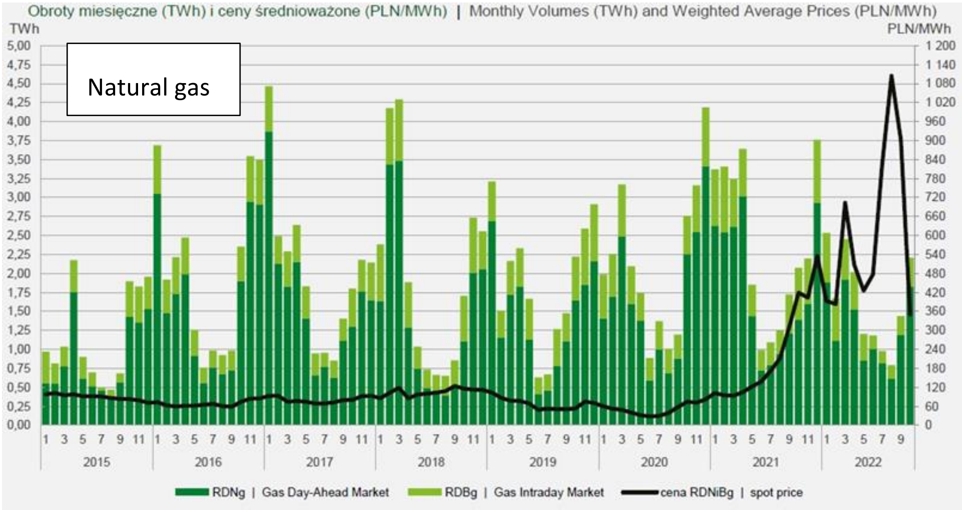


Figure 6-1: Evolution of market electricity and natural gas prices in Poland (PLN/MWh)[97]

Increased energy carriers' prices recorded at the Polish Power Exchange are predicted to stabilise at high level in the coming years. The table and figure below summarise data from statistics for contracts with delivery of electricity in the coming quarters of 2022 and next years.

Table 6-1: Historical data and contracts with delivery of electricity (weighted average electricity price)

	EUR/MWh	EUR/MWh
	Transactions 08.2022	**Transactions 10.2022**
2022 Q1	133	
2022 Q2	143	
2022 Q3	272	
2022 Q4	410	305
2023	378	224
2024	297	178
2025	330	

[97] Monthly Report, TGE – Polish Power Exchange, August 2022, https://tge.pl/dane-statystyczne

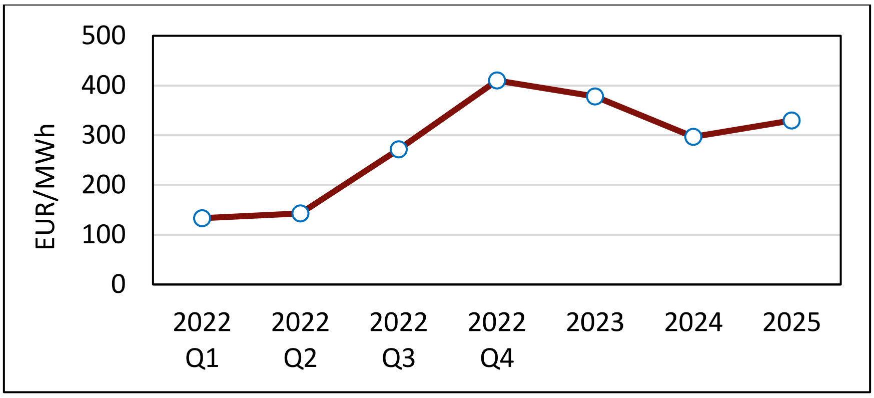


Figure 6-2: Market prices of electricity and contracts till 2025[98]

Wholesale energy prices have impact on energy prices paid by end-users. Three groups of network-type energy carrier prices are controlled by the Regulator (URE – Energy Regulatory Office):

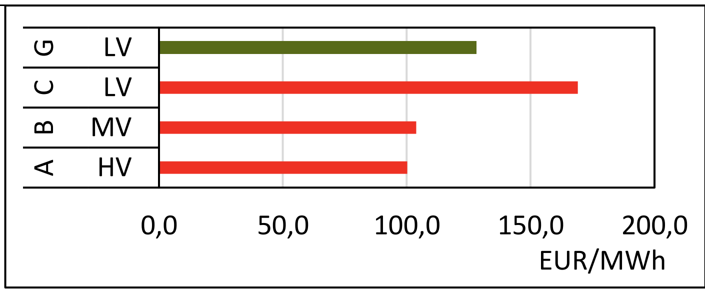
- electricity prices for households (both energy and distribution),
- natural gas for households (both delivered gas and distribution),
- district heat for all users (both heat and distribution).

Tariff system is based on historical data on energy consumption and costs. Energy companies from electricity, gas and heating sectors apply for tariff increase based on justified costs, including planned investments in development, energy efficiency and environmental protection. Recent dramatic change of fuels prices has resulted in general demand from energy sectors to increase price of delivered energy carriers to end-users. However only part of fuel prices increase is to be reflected in regulated tariffs, the Regulator does not allow for transferring of fuel prices to protected customers. As the result of that energy companies convey their costs to other tariff groups and unprotected customers.

Other electricity and gas consumers as well as users of coal, oil, LPG and fuel wood must pay market prices. Tariffs for public, commercial and industrial consumers increase following market prices of energy carriers.

The table below illustrates different average energy prices of electricity for different tariff groups, depending on the grid voltage supply (high, medium and low) and special tariff for households (G, LV) in 2021[99].

Tariff groups	Voltage	EUR/MWh
A	HV	100,2
B	MV	103,9
C	LV	169,0
G	LV	128,0



[98] Monthly Report, TGE – Polish Power Exchange, August 2022, https://tge.pl/dane-statystyczne
[99] Annual Report 2021 of the Regulator URE, 04.2022

Use of equipment utilised in Polish households for heating and preparation of domestic hot water (DWH) is shown below, for the latest published data of 2018. The larger share of solid fuels has hard coal used in towns, smaller share in countryside has fuel wood.

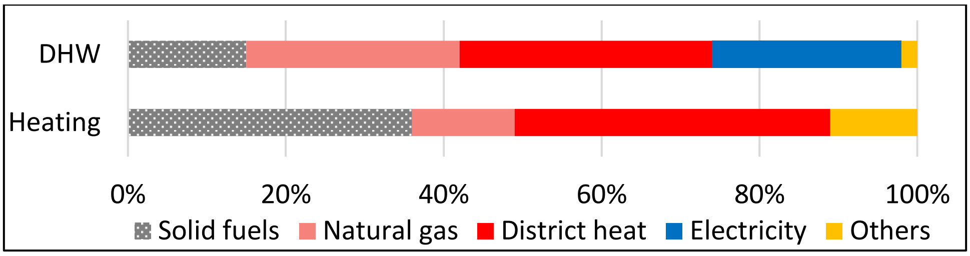


Figure 6-3: Equipment of households with space heating and water heating appliances[100]

Use of final energy carriers in households is summarised below.

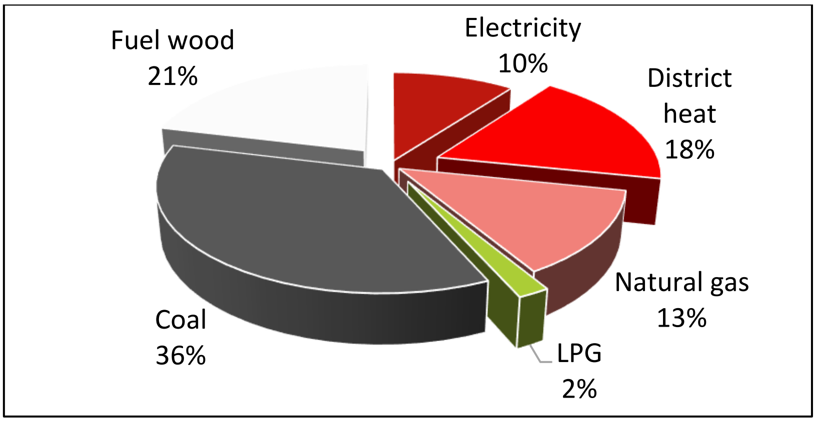


Figure 6-4: Use of final energy carriers in households in 2018 [101]

District heat is generated in over 70% from coal. Only few district heating systems in Poland, typically in big cities supplied from coal-fired CHP, fulfil criteria for being energy efficient. However, district heating systems are protected by law: they have priority in connecting new buildings, disconnections as well as installation of heat pumps to replace part or whole heat supply cannot by supported from public funds.

Geothermal energy

Geothermal energy within Poland is available in large quantities. Often geothermal sources are located under urban areas, which can reduce the cost of using them. Opportunities for the development of heat from thermal waters in Poland have not been used to an extent adequate to the resources of this energy and the benefits of its use. Between 2015 and 2021, the planned use of geothermal resources was not achieved. Although significant financial support for investment in geothermal during this period contributed to the development of this industry, due to the lengthy investment processes, the effects of this support will not be visible until after 2021. Although the country's geothermal resources have been well recognized, potential investors have had difficulty accessing information about the possibilities of developing them in specific locations. The implemented thermal water heat development projects made economic sense, with varying degrees

[100] Energy consumption in households in 2018, GUS Statistics Poland, 2019
[101] ibid

of effectiveness. The share of geothermal energy in the acquisition of RES in Poland is the lowest among the nine basic carriers of this energy.

District No.	Name of geothermal district	ΔT [°C]	GJ / m²	Area 10^9 [m²]	Available geothermal energy resources $\cdot 10^{21}$ [J]
		3 km	3 km		3 km
1	Grudziądzko-warszawski	70	260	70	18
2	Szczecińsko-łódzki	85	320	67	21
3	Podsudecki	90	340	39	13
4	Pomorski	65	240	12	3
5	Lubelski	80	300	12	4
6	Bałtycki	65	240	15	4
7	Podlaski	65	240	7	2
8	Przedgórze Karpat	80	300	16	5
9	Karpaty	70	260	13	3

1. The National Fund for Environmental Protection and Water Management is currently offering a priority program entitled "Making Thermal Waters Available in Poland." **The purpose of the program is to carry out works and geological works related to the exploration and recognition of thermal water deposits for their accessibility to use the obtained heat/energy for heating. Beneficiaries in the program may be local government units or unions of local government units.**

The budget for the program is up to PLN 300 million, including up to PLN 300 million for non-refundable forms of financing. The call for proposals is carried out in a competitive mode.

The forms of financing are grants, and the intensity of financing is up to 100% of eligible costs. The program will be implemented from 2020 to 2025, with commitments (understood as signing of agreements) being made until 2022, and funds disbursed until 2025.

2. From 2019 to 2025, the "Polish Geothermal Plus" program is in operation. The goal of the program is to increase the use of geothermal resources in Poland. Undertakings that have a chance to receive funding are divided into obligatory and optional. **Among the former are: the construction of a new, expansion or modernization of an existing geothermal heat/thermal power plant/electric power plant, based on a geothermal source, or the modernization or expansion of existing energy generation sources with a geothermal heat/thermal power plant/electric power plant, based on a geothermal source, or the drilling or reconstruction of a geothermal borehole, excluding the first exploratory well. The beneficiaries of the program are entrepreneurs performing business activities.**

The budget for the Poland Geothermal Plus program is PLN 600 million with the possibility of increasing it. Two forms of subsidies are envisaged: grants - up to 40 percent of eligible costs (up to 50 percent for geothermal projects using ORC technology) and loans - up to 100 percent of eligible costs.

The Poland Geothermal Plus Program will be implemented between 2019 and 2025, with commitments, understood as signing contracts, to be made by 2023, and disbursement of funds foreseen by 2025.

3. The Ministry of Climate and Environment has developed the "**Long-term Program for the Development of the Use of Geothermal Resources in Poland."** This is a roadmap for geothermal development until 2040, with an outlook until 2050. Program recognizes areas and opportunities for the use and financing of heat pumps. Link to the program: https://www.gov.pl/attachment/bbca8212-94df-4392-bfe1-15e2e3fd7a35
4. Norwegian Financial Mechanism, EEA Financial Mechanism. The EEA Financial Mechanism and the Norwegian Financial Mechanism (i.e., the so-called Norwegian and EEA Funds) are a form of non-refundable foreign aid granted by Iceland, Norway and Liechtenstein to the new EU members - a dozen countries in Central and Southern Europe and the Baltic States. It covers financing areas such as high-efficiency cogeneration, modernization of networks and sources in district heating systems, energy efficiency improvements in schools, geothermal, small hydroelectric power, and pellet production projects. The budget is €111,290 million over the period 2021-2024. The amount includes the grant available for the indicated activities and national co-financing.

7 Appendix G: Spain

7.1 Cultural, economic, and social aspects

The *Integrated National Energy and Climate Plan 2021-2030*, sent by Spain to the European Commission in 2020, raises targets for 2030 that look ambitious (such as 74% of renewable energy share in electricity generation or the GHG emission reduction of 69%, against 1990 emission level). According to this report, the trend indicates that if no measures are implemented to achieve this target scenario, only a 52% penetration rate of renewables in electricity generation will be achieved[102].

To achieve these goals, it is important that all relevant parties are involved, and that the way in which energy is used is linked to cultural practices and daily habits. Therefore, to achieve these climate goals, it is essential to understand these routines and how they affect energy use. The benefit of behavioral change within society can potentially lead to greater energy savings among the population, greater use, and acceptance of sustainable energy sources.

As explained in the Deliverable 2.5 of ENERGISE, Spain, with 61 identified and described SECIs (Sustainable Energy Consumption Initiatives), is at the very top of the mapping conducted by the project across 30 European countries. Additionally, and perhaps even more importantly, 36% (22 initiatives) have been classified as the ones trying to obtain 'Changes in Complex Interactions' – the highest-ranking category of ENERGISE typology. This percent is much higher than in most other countries – the average rate for all 30 countries is 13.5%. 3% of Spanish SECIs are pursuing 'Changes in Everyday Life Situations,' 33% are promoting 'Changes in Individuals' behavior, and the remaining 28% are proposing 'Changes in Technology' to achieve energy savings[103].

Another initiative that has been carried out by the Spanish government is incentive programs for heating and cooling network projects using renewable energy sources that help to achieve the objectives set out in the cross-cutting policies of the Spanish government, such as the development of the circular economy, the Demographic Challenge and the Fair and Inclusive Energy Transition. Although in Spain it is not usual to find district heating/cooling systems, the deployment of heat and cold supply networks based on renewable energies is part of the solution to achieve climate neutrality by 2050, as they contribute to the structuring of the territory and the development of rural areas and reduce imports of natural gas and other fossil fuels. They also promote a change in Spain's production model, generating new jobs and boosting economic activity in a context of recovery[104].

As for the electricity mix in Spain, according to IEA the electricity generation by source is the following for the last thirty years:

[102] https://www.sciencedirect.com/science/article/pii/S0360544221026864
[103] http://www.energise-project.eu/sites/default/files/content/D2.5_Spain.pdf
[104] https://www.idae.es/ayudas-y-financiacion/programas-de-incentivos-proyectos-de-redes-de-calor-y-frio-que-utilicen

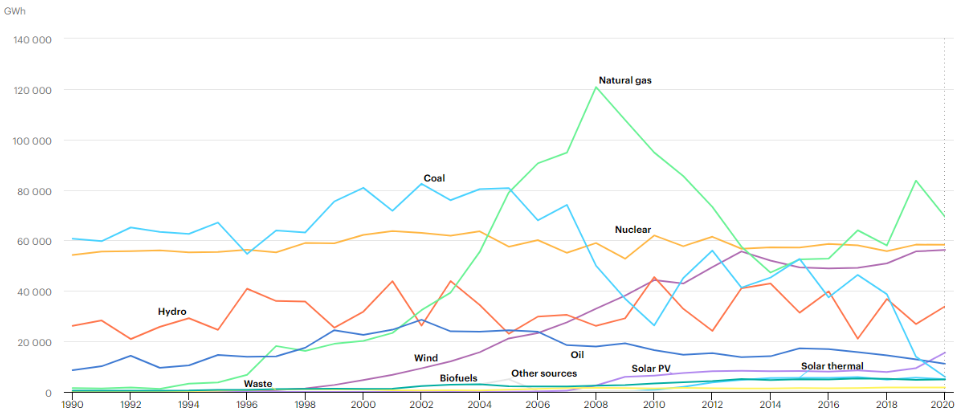


Figure 7-1: Electricity generation by source. Spain 1990-2020

As it can be noted, Spain continues depending on natural gas considerably; in fact, the gas lobby has a lot of power-, although the renewable share has increased significantly in the last thirty years according to IEA as can be seen in the figure below:

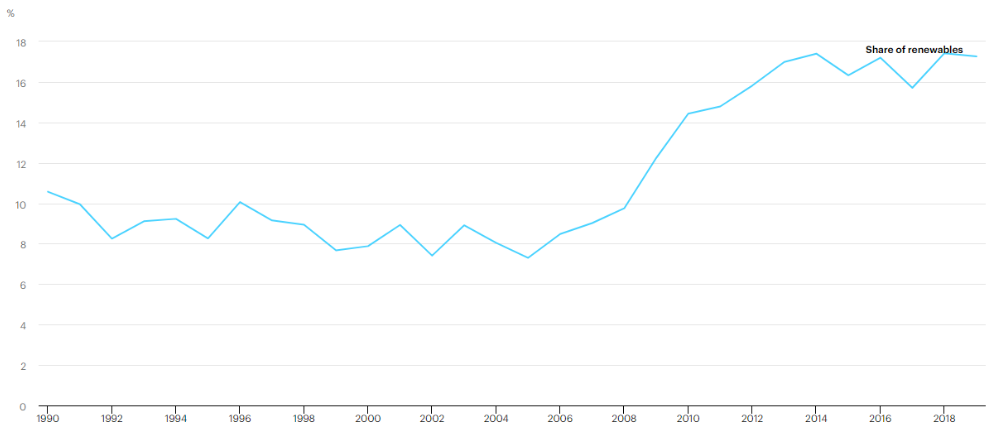


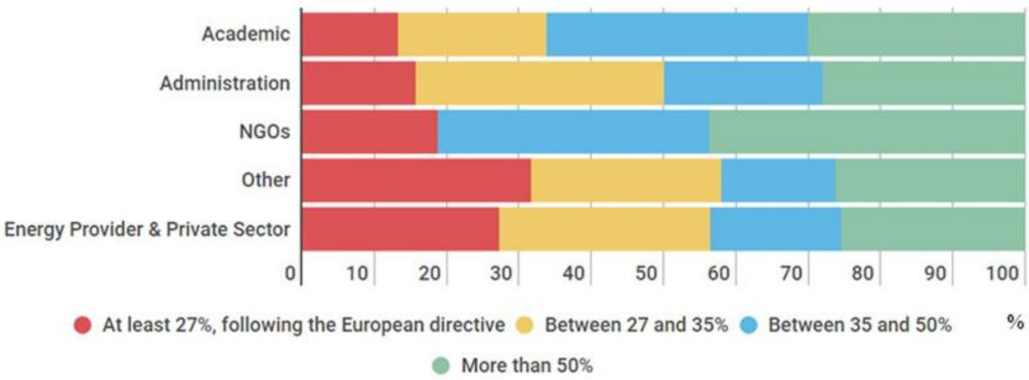
Figure 7-2: Renewable share in final energy consumption (SDG 7.2). Spain 1990-2020

Notwithstanding its considerable progress to date on decarbonizing and increasing the share of renewables in the electricity sector, Spain's total energy mix is still heavily dominated by fossil fuels. Notably, the transport, industry and buildings sectors all have considerably more work ahead of them to meet the country's targets for renewables penetration and decarbonization.

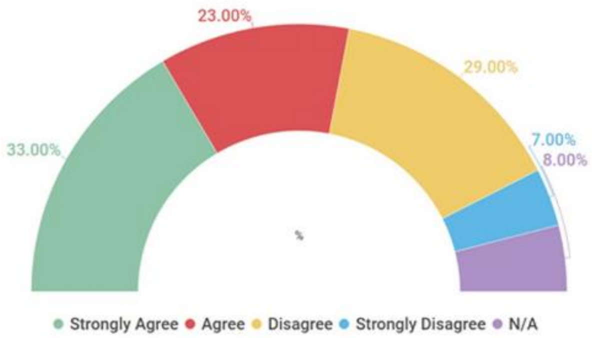
In addition to the official target set by the government, some studies have been carried out in which different stakeholder groups with different backgrounds give their opinion on what the target for renewables in final energy demand will be by 2030 and their opinion on the possibility that renewables will account for close to 100% of the national energy mix by 2050[105].

As for the target of renewables (%) to be in the final energy demand by 2030, the different stakeholder groups stated that only around 30% of them believe that renewables penetration will be higher than 50%.

[105] https://www.sciencedirect.com/science/article/pii/S2214629619301033



As for the opinion on possibility of renewables to represent almost 100% of the energy mix by 2050 is the following:

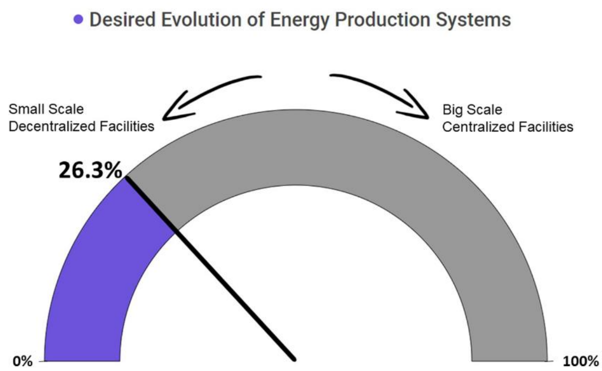


In addition to all that has already been mentioned, one of the peculiarities of Spain is that it has very different climatic zones (very hot summers -and increasingly so- and very cold winters). However, on the coast the winter is very mild, and no heating is needed.

7.1.1 Residential

In Spain the residential sector is characterized by decentralized energy systems, so each home has their own cooling/heating system.

In fact, according to some studies, in which different stakeholder groups with different backgrounds give their opinion on this issue, it seems that it will remain decentralized[106].



One of the reasons why it is not so popular to have centralized systems is that until recently the consumption was not individualized for each house, so that the cost could easily increase due to

[106] https://www.sciencedirect.com/science/article/pii/S2214629619301033

improper use by others. Heating is the most important end-use in the residential sector, as can be seen in the following figure (IEA):

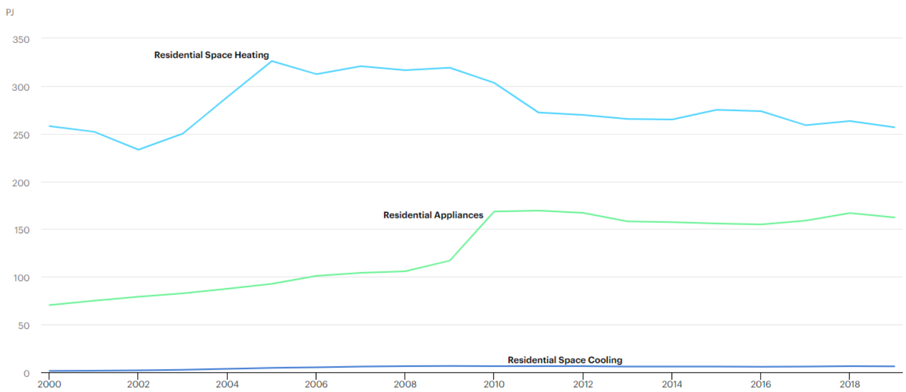


Figure 7-3: Total consumption by end use - residential. Spain 2000-2019

For heating and SWH, natural gas with radiators is traditionally used. However, as NG price is rising astronomically, feasibility studies of geothermal energy are increasing. Despite the fact that geothermal energy exists practically in the entire national geography, "*penetration in Europe is being much higher than in Spain*", according to Margarita de Gregorio, director of Geothermal at APPA, the employer's association for renewables, and coordinator of the Spanish Geothermal Technology Platform (Geoplat). This delay is explained, in part, because "*this energy source started developing only in heating and in Spain the demands are not as high as in other places on the continent, but since it has been shown that it can also be applied in cooling it is being implemented more and more , although the Nordic countries are ahead of us*", says Teresa Magraner, professor in the department of applied thermodynamics at the Polytechnic University of Valencia (UPV) and an expert in geothermal energy. Experts consider that there are several factors that limit the growth of this energy: "*The technologies are highly controlled, mature, efficient and competitive, but the fact that you have to drill is a brake*". Another obstacle is regulatory: "*There is no specific regulation. Each autonomous community has its own or it does not, which makes it very difficult to process an installation". Experts also lack greater institutional support: "The same political will that exists for the promotion of electric renewables should exist for thermal renewables.*"

As for the summer, ASHP have been gaining popularity. IDAE statistics reveal that, in 2019, of the total number of plants installed, Air-to-Air (reversible) as an energy source and means of distribution accounted for 98.4 % of the total. It is also important to note that in 2019, 77.8 % of heat pumps installed in Spain were registered in the residential sector.

As for the use of renewables, the Spanish technical building code requires that a % of your demand is covered by renewables. The most popular systems traditionally used for this is the use of solar thermal energy for DHW. However, in the latest version of this regulation, aerothermal energy is accepted as renewable when extracting heat from the air, so the installation of solar thermal systems has decreased.

Besides that, the government is pushing for energy communities. You can feed into the grid or share it with your neighbourhood. Both for thermal and electrical energy. Industry is pushing the government to develop this. In Spain, collective self-consumption already exists, and the energy obtained by this mechanism is entitled to a reduction in the cost of tolls. However, it is only possible to share surpluses with those consumers who are 500 metres away. This is insufficient if we think of sparsely populated areas or the use of local public buildings to participate in shared self-consumption with their citizens.

Recently, the Spokesperson for Transport announced that the Government plans to extend the 500-metre limit for collective self-consumption in energy communities, although it is not known what the new limit will be. This is a request that the sector has been making for some time. Energy communities, thanks to their geographical delimitation, are the perfect candidates to take advantage of collective self-consumption and, thus, offer attractive discounts to consumers.

Additionally, various initiatives targeting household behaviour in the field of energy have been implemented. For example, the Energy Diversification and Saving (IDAE) promotes and facilitates an efficient use of energy by SMEs and households through communication campaigns and information and training programs. The awareness-raising campaigns have contributed to tracking the evolution of the Spanish consumer profile in the last ten years and to better direct actions aimed at achieving quantifiable energy saving results. However, systems such as BMS or EMS, which in the residential sector are known as domotics, are not very widespread in households.

7.1.2 Services & public

In Spain, offices are mostly electrified for heating and cooling. Typically, air-to-air, or air-to-water systems are used. VRV or fan coil systems are commonly used, as well as AHUs and heat recovery units. In contrast to residential buildings, office buildings and other services require a lot of cooling, as can be observed (IEA).

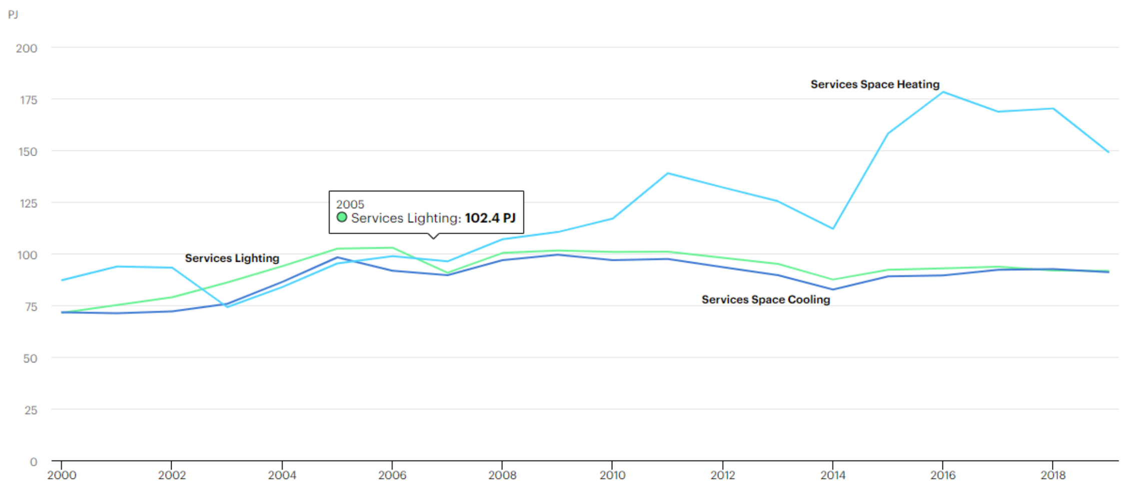


Figure 7-4: Total consumption by end use - services. Spain 2000-2019

One important aspect to mention is that the government has recently limited air conditioning in shops, offices, and transport to 27 degrees Celsius and heating to 19 degrees Celsius, a measure aimed at reducing HVAC consumption in the service sector.

In contrast to the residential sector, in offices it is quite common to have a BMS and EMS to monitor and control all building consumption, including HVAC equipment. In fact, there is a large market for this type of solution with manufacturers such as Schneider and Siemens.

In addition, many companies hold sustainability certifications such as LEED or BREEAM, which require, among other things, an increase in the efficiency of HVAC equipment and/or an increase in the percentage of renewable sources in final consumption.

Regarding the penetration of renewables, all companies tend to install PV panels on the roof if they have the option, to cover a % of the consumption. María Canal, the economic advisor of the European Commission's representation in Spain, reports that, in the framework of the European Commission's communication on the REPowerEU plan in May 2022, a revision of the Energy Performance of Buildings Directive is proposed to make the installation of rooftop solar energy mandatory in the following cases: in all new public and commercial buildings with a usable floor area over 250 square metres in 2026, and in all existing public and commercial buildings with a usable floor area over 250 square metres in 2027. This proposal is still under consideration.

Furthermore, in May of this year, the Council of Ministers approved a Plan of energy saving and efficiency measures, aimed at the General State Administration and state public sector entities. Among the measures are the establishment of switching on and off times for buildings, the reinforcement of remote working and incentives for the use of public transport.

7.2 Building codes and regulations

Spain counts with a well stablished legal framework that has been developed taking into account the strategic national plans as well as EU directives.

The *Integrated National Energy and Climate Plan 2021-2030*, was sent by Spain to the European Commission in 2020. The plan has been supported with other legislative and regulatory measures as well as incentives. Strategies and incentives for particular subjects have also been elaborated as it will explained with more detail on this report.

The latest modifications on the legislation have been directed to support the implementation of the PNIEC and reach the proposed objectives. There is a strong legal framework that regulates the installation of solar photovoltaics, solar thermal, aerothermal systems, building retrofits and other relevant sources of energy for the building environment in Spain.

Moreover, in the framework of the NextGenerationUE the Government has implemented a new plan that puts partial emphasis on energy consumption and generation, the *Plan de Recuperación, Transformación y Resilencia* (PERTE, 2022).

When taking into account the construction sector, the most important legal framework would be the "*Código Técnico de la Edificación*, (CTE). The CTE is the regulatory framework that establishes the basic quality requirements that buildings must meet in relation to the basic safety and habitability requirements. It applies for both new construction and interventions on existing buildings. The CTE includes the energy saving and thermal insulation regulation as well as permits the transposition of European legislation 2010/31/UE (2010/31/UE European Union, 2010). The CTE sets also objectives on renewable energy generation and energy efficiency for each, residential, commercial, offices and public sector.

The CTE is complemented with the "*Reglamento Instalaciones Térmicas en los Edificios*" *(RITE, 2007 latest update 2021)*. The RITE establishes the conditions to be met by installations designed to meet the demand for thermal comfort and hygiene through heating, air-conditioning and domestic hot water systems and equipment, in order to achieve a rational use of energy. The RITE establishes various energy efficiency requirements, such as: energy efficiency in heating and cooling equipment, insulation conditions in thermal fluid equipment and pipes, regulation and control conditions in air-conditioned premises, use of available renewable energies, incorporation of energy recovery subsystems and use of residual energies, compulsory consumption accounting systems, gradual disappearance of more polluting solid fuels, gradual disappearance of less efficient generating equipment. As an example, recently a temperature set point adjustment has been approved for some commercial, offices and public buildings.

The PNIEC also seeks to guarantee consumers the right to produce, consume, store, and sell their own renewable energy, and to assess both the barriers and the development potential of renewable energy self-consumption. (European Commission, 2021). The legal framework for self-consumption is well defined. All applicable legislation can be found on the IDEA (Self-consumption regulatory framework).

New legal figures have been implemented in Spain to increase the renewable production and share of energy production with a larger distributed generation market. Energy communities have been defined in the legislation as a key actor in the energy transition. (RD 23/2020, 2021). The creation of these communities enables the distribution of renewable energy generation (both thermal and electrical) among close individual shareholders through the public electric grid. (IDAE Comunidades energéticas, 2022). Some of the latest modifications have been proposed to lift some barriers for the creation of these communities as the recently published proposal of increasing the accepted distance in between particular entities to 2km. Other barriers are being lifted as the interest of the population is increased and the administrative procedures are simplified. However, one of the most difficult barriers to lift come from the residential sector where involved neighbors have to reach an agreement.

Not only generation, consumption and energy saving measures are regulated but also the digitalization of the sector in order to better measure and implement saving measures. Individual smart metering is mandatory for electricity and natural gas consumption and has been implemented in most of the market (CNMC, 2021). Also noteworthy is the electricity and gas meter benchmarking study (Benchmarking Smart metering deployment in the EU-28, European Union, 2020), which analyses the deployment of smart meters in EU countries, Spain being one of the most advanced countries to comply with the European regulation.

7.2.1 Residential

The main regulations that apply to the residential sector in the energy field are applied through the regulations already mentioned. However, some mayor recent changes are of special interest for the analysis.

Prior to the current technical code, communal heating systems made no discrimination for each individual user’s consumption, which led to very inefficient expenditure, as payment is independent of the energy consumed and the user is not conscious of its consumption. A regulation has been included whereby it is compulsory to install individual kilocalorie meters for each of the consumers, which will be a very important energy saving measure.

For solar and energy storage installations, there is still a gap regarding the special regulations to be applied, and special requirements are generally applied by insurers. It is to be expected that when this type of installation becomes more widespread, the applicable regulations, especially fire and safety regulations, will be more restrictive.

7.2.2 Public sector

The state has a compromise to reduce the energy consumption of its buildings to almost zero by 2030. The Ministry is elaborating a specific strategic plan “*Plan de reducción de consumo energético en la Administración General del Estado (AGE)”.*

Spain recent specific measures have been taken for implementing energy saving and efficiency measures aimed at the General State Administration and state public sector entities. The main objectives of this plan are to rationalize the use of administrative buildings and facilities, as well as to establish ways of organizing the work of public employees that result in energy savings. The main measures are: rationalization of switch-on and switch-off times for air-conditioning, lighting and office equipment installations. Maintenance of an optimum level of occupancy of the buildings. Control of adequate temperature conditions. Promotion of the installation of photovoltaic panels for self-consumption in public buildings and infrastructures. photovoltaic panels for self-consumption. Optimization of outdoor lighting in buildings with on/off time and light level control. (MITECO, 2021).

7.3 Energy market rules and tariffs

The energy market in Spain has a established legal framework that includes regulation on market rules and tariffs. The main energy sources (electricity, natural gas, and fuel and biofuels) are regulated and supervised by the government agency *Comisión Nacional de los Mercados y la Competencia* (CNMC). Both the electric and natural gas market have a mix of regulated and liberalized tariffs where the consumer has the opportunity to decide the tariff based on the available offer. In the image below a distribution of the consumers as of the 3rd quarter of 2021 can be found. In the second figure the same data is introduced for the Natural gas energy market. It must be taken into account that during the month of November 2022 a high percentage of consumer have moved from the natural gas liberated market to the regulated market taking advantage of lower prices (Informe De Supervisión De Los Cambios De Comercializador, Tercer Trimestre De 2021, Ref. Is/De/014/21).

TIPO MERCADO	3T 2018		3T2019		3T 2020		3T 2021	
	Suministros	% Total	Suministros	% Total	Suministros	% Total	Suministros	% Total
Mercado Libre	18.084.129	61,5%	18.476.314	62,6%	18.697.647	63,1%	19.339.486	64,9%
Mercado Regulado	11.297.848	38,5%	11.042.646	37,4%	10.946.857	36,9%	10.476.514	35,1%
TOTAL	29.381.977	100%	29.518.960	100%	29.644.504	100%	29.816.000	100%

Figure 7-5: Evolution of electricity distribution points per market type. 2018-2021. Source: CNMC based on information provided by marketer.

TIPO MERCADO	3T 2018		3T2019		3T 2020		4T 2021	
	Suministros	% Total	Suministros	% Total	Suministros	% Total	Suministros	% Total
Mercado Libre	6.279.558	79,8%	6.341.780	80,1%	6.381.479	80,2%	6.425.291	80,6%
Mercado Regulado	1.592.768	20,2%	1.579.776	19,9%	1.579.745	19,8%	1.543.615	19,4%
TOTAL	7.872.326	100%	7.921.556	100%	7.961.224	100%	7.968.906	100%

Figure 7-6: Evolution of natural gas distribution points per market type. 2018-2021. Source: CNMC based on information provided by marketers.

The distributed generation market has also a strong legal framework that is evolving to solve some of its main barriers. Consumers with self-generation can opt to commercialize the excessive energy for some tariffs community energy trading, electricity feed-in tariffs, bilateral agreements with a marketer or for its net self-consumption compensation. The regulation is established as the self-consumption is efficient as excessive generation is compensated but the installations are not largely oversized on capacity.

7.3.1 Incentives

Most of the incentive's legal frameworks are regulated by the state and are implemented within the framework by each autonomous region, who is also the responsible for deciding on the applications.

Each autonomous region has its responsible organization and budget. Those organizations and available regional budgets per regions can be consulted on the IDAE (Autonomous organizations, IDAE).

Incentives on CAPEX and taxes have been implemented extensively on every autonomous region with variations on the incentives. CAPEX incentive may vary on quantity and some regions might include tax incentives and others do not. Incentive regional programs are usually divided on a sectorial and technology bases, as it can be seen on the example in the figure below.

The incentives on the installation of self-consumption, energy storage, and renewable thermal energy systems for hot water such as solar thermal, biomass, geothermal, hydrothermal, and aerothermal have been very successful. For example, in Madrid Autonomous region programs 4, 5 and 6 from the figure below have no more budget and are being extended. The regulatory framework and main characteristics can be found on the IDEA (Energías Renovables en autoconsumo, almacenamiento, y térmicas, IDEA).

Table 7-7: Example. Budget by programs for the Madrid Autonomous Region for self-consumption, storage, and renewable thermal generation. Source: FENERCOM, link. Source: FENERCOM, link.

Program 1:	Implementation of self-consumption installations in the services sector.	Self-consumption	€ 31.770.704,90
		Storage	€ 6.354.140,80
Program 2:	Implementation of self-consumption facilities in other productive sectors.	Self-consumption	€ 24.965.060,40
		Storage	€ 4.934.832,20
Program 3:	Incorporation of storage in existing self-consumption installations in the services sector and other sectors.		€ 5.804.627,40
Program 4:	Implementation of self-consumption installations in the residential sector, public administrations and the third sector.	Self-consumption	€ 73.610.318,50
		Storage	€ 10.091.731,30
Program 5:	Incorporation of storage in existing self-consumption installations in the residential sector, public administrations and the third sector.		€3.129.190,10
Program 6:	Implementation of thermal renewable energy installations in the residential sector.		€ 15.245.616,70
Total			**€ 175.906.222,30**

Incentive programs have been established to promote the deployment and incorporation of thermal renewable energies in the sectors of the economy, including the residential sector, and the public sector. The following two incentive programs for the implementation of thermal renewable energy installations have been approved (IDAE, implantación de instalaciones de energías renovables térmicas en diferentes sectores de la economía RD 1124/2021. PRTR),:

- Program 1: Implementation of thermal renewable energy installations in the industrial, agricultural, services and other sectors of the economy, including the residential sector.

- Program 2: Implementation of thermal renewable energy installations in non-residential buildings, establishments, and public sector infrastructures.

% max CAPEX offset	Baseline	Large company	Medium company	Small company
Program 1	35%	35%	40%	45%
Program 2	70%			

Some figures might slightly vary depending on other factor better explained on the regulation. The incentive programs approved by RD 1124/2021 will be in force until 31 December 2023.

On the other hand, incentives for projects in which distributed heating or cooling networks use renewable energy are also promoted to reduce dependency on fossil fuels (IDAE, Programas de incentivos a proyectos de redes de calor y frío que utilicen fuentes de energía renovable). It defines incentives for the following projects, under evaluation on economics, administrative feasibility, technical criteria, and demonstration among others.

- New heating and cooling network, including one or more generation plants using exclusively renewable energies and one or more distribution networks with energy exchange connections to consumption centres.
- Expansion of an existing generation plant, by incorporating new generation equipment using renewable energies.
- Extension of an existing distribution network, including the network itself and new exchange connections. These projects must use existing generation plants that use renewable energies.

Finally, as of the 17th of November 2022, the *Ministerio para la Transición Ecológica y el Reto Demográfico*, launched the first call for new business models focused on the decarbonization, digital transformation and renewable energy (IDEA, Ayudas para nuevos modelos). The first call will have a budget of 100 million. They will support innovation, decarbonization and improved integration of renewable energies, and the promotion of 'Startups'. They will finance energy system flexibility services, regulatory sandboxes, energy aggregators, demand management, digital transformation, second life of storage equipment among others. This initiative will be supported by the recent regulatory framework for Sandboxes *(RD568/2022, July 2022)*.

Building retrofits have also been incentivized through CAPEX and taxes reduction. Special attention has been placed on regions with a low population density. This will be specifically mentioned below in this section.

7.3.2 Residential and office

On top of the previous incentives, there is a specific program for retrofit of existing residential and offices buildings. The retrofit of buildings has been strongly incentivized through CAPEX, taxes and financing with measured success. The overall objective of the actions is to reduce non-renewable energy consumption in households by at least 30%, and to decarbonize and reduce heating and cooling demand by at least 7%. It is important to prove the reduction of consumption and for this purpose an expert must issue an energy certificate for the house or building before and after the action. The most effective way to reach the thresholds required under the PRTR is to act on the building envelope, installing insulation in both facades and roofs, and replacing window frames with thermally broken ones to prevent cold from "sneaking in" through the windows. The incentives also exist for improving efficiency of thermal installations and lighting efficiency (Ministerio de transportes, Movilidad y Agenda urbana, 2021) (IDAE, PREE5000 Rehabilitación Energética De Edificios En Municipios De Reto Demográfico).

7.3.3 Public buildings

On top of the previous incentives, national buildings can benefit from other incentives aiming to rationalize the use of the buildings and working habits that lead to energy savings. Among the measures are the establishment of switching on and off times for buildings, the reinforcement of remote working and incentives for the use of public transport.

Also retrofitting incentives have been aimed to reduce the energy consumption with direct CAPEX incentives. The CAPEX is up to 50-80% offset depending on the autonomous region (IDAE, Renovación Energética De Edificios E Infraestructuras Existentes De La Administración General Del Estado).

8 Appendix H: Denmark

8.1 Cultural, economic, and social aspects

The traditional, collective energy supply

"The Danish energy supply has been dominated for half a century by the supply of large-combined heat and power (CHP) plants, producing both electricity and heat. The subsequent distribution of heat and electricity is then carried out through separate collective grids to end users, which range from individual households to institutions and businesses. Following the oil crisis in the 1970s, this system was supplemented by new electricity production from wind turbines, and by a nationwide transmission and distribution network for natural gas, which at the time worked mainly as a replacement for the oil which still played a major role outside district heated areas. This way to structure the supply of electricity and heating has clearly defined divisions of labour between CHP plants and wind farms on the one hand, responsible for the production of electricity and heating, and on the other hand an extensive network for distributing electricity, district heating and natural gas to end users. This energy system design, based on a central supply of electricity and heating, has become increasingly dominant. Smaller CHP plants are now replacing individual oil and gas boilers in the heating supply, as district heating is established in both smaller cities and suburbs to the larger cities.

Denmark has been a pioneer in many ways when it comes to the involvement of citizens in setting up collective solutions for joint energy supply. It has provided citizens with the opportunity to engage with the energy system as both producers and distributors, either through municipalities or by direct ownership through cooperatives etc. Municipalities have been able to secure the supply of utilities through private legal entities, such as cooperatives, as long as these companies have followed the principle of equality vis-à-vis stakeholders in their business. In concrete terms, this means equal grid access and pricing terms for all.

The long-standing local cooperation between public and private organizations has shaped the development of the various public utility sectors and provides the basis for much of the local utility structure we see today. Thus, it should be noted that the public sector has historically been actively involved in supporting the development of a local energy supply controlled by consumers/local citizens. This is unique when compared with other countries in Europe, which have a tradition of private ownership of energy production and distribution companies (Concito 2016; Annual Environmental Strategic Meeting 2017)." (Handbook for Energy Communities 2020:14ff).

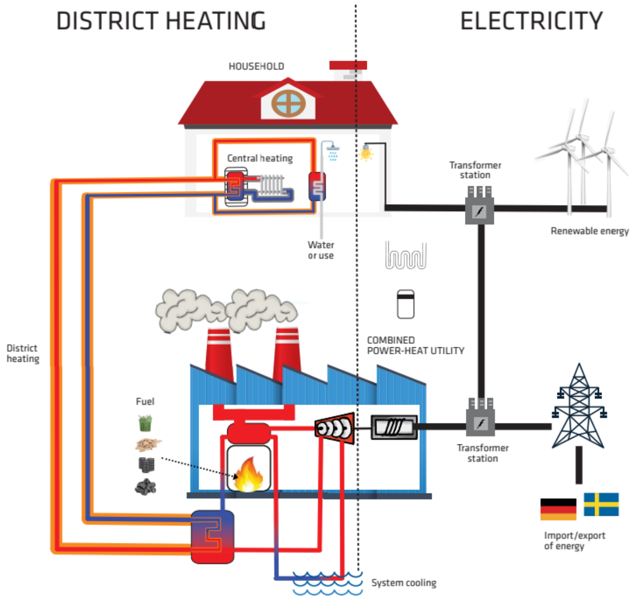


Figure 8-1: The Danish supply model based on cogeneration heat and power utilities, distribution companies and customers (in case shown as a single-family house but could have been a tenant building or larger company)

In Denmark, there is a long history of community-owned energy supply. The electrical power production was owned by consumer cooperatives and municipalities; power production was generally based on the non- profit principle. This was changed when Denmark implemented the European Internal Energy Market policy liberalizing the energy supply and allowing companies to take over the power plants.

Today the district heating, which is widely spread in almost all Danish towns being by far the largest source in terms of heat supply, is still organized in a form of non-profit companies owned by consumer cooperatives and municipalities.

In the 1980´s and 1990´s, a major part of windmills raised in Denmark were owned by local citizens organized in cooperatives. Today only 20% of the local windmill projects are reserved for local citizens' ownership. This has been an important factor in the rising number of local protests.

Solar cells for electricity production were very limited in Denmark until the recent 2-3 years. Until the end of 2012 Denmark had net-metering (NEM) for households installing up to 6 kW PV cells. It was working during the whole year; therefore, households could produce solar electricity mostly in summer and 'get it back' from the grid in winter and during the night. This system in combination with declining prices of solar panels and with information campaigns by a few utilities, NGO groups and small local firms resulted in a big rise in the numbers of small photovoltaic (PV) plants. The Energy production from solar in Denmark from 2012 to 2021 was 104 gigawatt hours in 2012 to 1309 gigawatt in 2021.

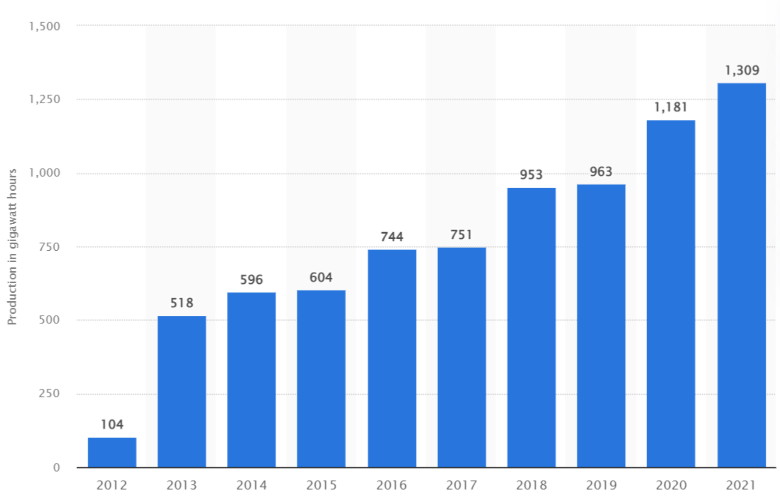


Figure 8-2: Energy production from solar cells in Denmark from 2012 to 2021 (in gigawatt hours) (Source: Statista[107], 2022)

Generally speaking, the view on climate change action amongst the Danish population is positive. There is a longstanding tradition of being on the forefront when it comes to wind energy in particular, going all the way back to the energy crisis's of the 70's.

According to the Danish Ministry of Climate, Energy and Utilities, more than 2/3 Danes think that Denmark should be leading the way when it comes to the green transition. In the 2019 survey about the Danish population's attitude towards climate dilemmas, the respondents were asked to which degree they agree that Denmark should lead the way when it comes to the green transition, even though such leadership/front position comes with a certain economic cost here and now. 25% of respondents answered that they strongly agree, 42% that they agree, 23% that they don't agree nor disagree, and only 7% and 3% disagree or strongly disagree (Norstat on behalf of the Danish Ministry of Climate, Energy and Utilities, 2019: Q7[108])

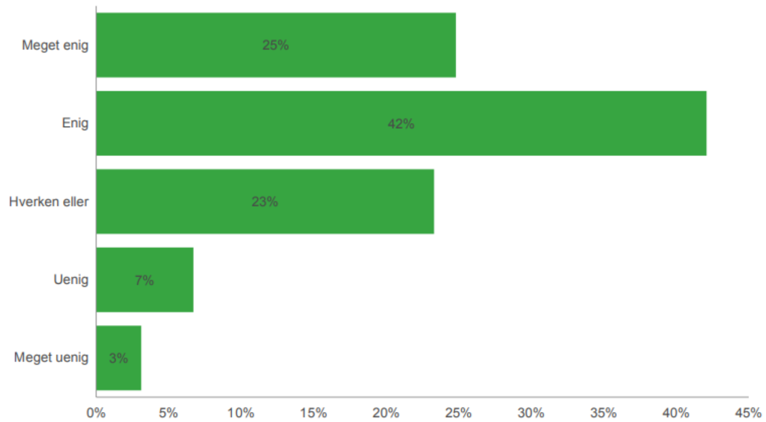


Figure 8-3: Survey by Norstat on behalf of the Danish Ministry of Climate, Energy and Utilities, 2019: Q7.

107 https://www.statista.com/statistics/991590/energy-production-from-solar-cells-in-denmark/
108 https://kefm.dk/media/6502/resultat-af-survey-om-danskernes-holdning-til-klimadilemmaer.pdf

Citizens' initiatives

Getting the citizens onboard in the green transition of the energy system in Denmark is crucial. Having a strong tradition for organization in the civil life takes some of the responsibility away from the political decision makers and puts it onto the civil sphere where citizens are mobilized. Thus, there are grassroot initiatives regarding energy renovations, but more often than not, citizen initiatives happen in close cooperation of public-private partnerships with the authorities who in recognition of the tradition seek to engage the citizens in all stages and on multiple levels of energy renewal projects. Examples of such initiatives include the project "Sol over byen" aiming at creating energy communities and exploring the social and management related advantages obtained by developing local energy communities in local areas of Copenhagen. The project has worked with a dual scope of examining both the perspectives of the citizens/social perspective and that of the government/municipality/management perspective.[109]

EnergyBlock is the test site of Copenhagen Solutions Labs for Decentralized Energy and Blockchain solutions. It explores the potential of utilizing renewable energy sources in an existing urban environment and connecting It to an open blockchain for energy. The ambition is to showcase and demonstrate to citizens, investors, and decision makers a proof of concept for scaling in other parts of Copenhagen, as well to other cities. EnergyBlock is developed from a sustainability perspective. The introduction of renewable energy sources introduces falling prices on energy. While this is a benefit to consumers, it also challenges present infrastructures to its capacity and to cover the capital expenditures of the existing investments.

EnergyBlock is analyzing the benefits of combined local energy production and local food production from a rooftop greenhouse while accommodating a social agenda of local job creation. By doing this, it will add a multiple bottom line for investments in sustainable, localized energy solutions. The project is situated in the northwestern district of Copenhagen, called "Nordvest".

8.1.1 Residential

Households in Denmark consist of 5.9 million citizens of the country, living in approximately 2.7 million households. Due to the Danish winter climate, all households have a need for heating, and a part of this need is covered through the collective district heating – "fjernvarme" – while other households are equipped with individual types of heating such as gas and heat pumps (DEA 2022:22).

The household sector in the Climate Status and Outlook (as well in this appendix) are to be understood as the consumption and emissions relating to household's individual heating, while district heating and electricity is described separately in another chapter about the electricity and district heating sector.

Though the Danish households only account for the 4 percent of the total GHG emissions in 2019, they account for 30 percent of the total energy consumption. The consumption split is approximately 15 percent for electricity, and 85 percent for heating.

The Danish Energy Agency expects that the heating consumption and warm water consumption will rise a bit towards 2025 and thereafter fall (jf. KF22 sector note 3A). The consumption of electricity for lighting and appliances are expected to top in 2020 and fall thereafter.

[109] https://kk.sites.itera.dk/apps/kk_pub2/pdf/2320_7be14b5d53c9.pdf

There have been no new political actions towards the heating of the households in 2021, and the future development is expected to be driven by prior political deals. Of course, due to the situation in Ukraine, the market price on natural gas has been higher than usual, and the war has created some insecurities in the markets, which naturally can have a long-lasting effect on the Danish households preferred type of heating (DEA 2022:24).

Political agreements, which were also included in KF21, including tax adjustments that make it cheaper to heat with electricity, regulatory changes that remove obstacles to the conversion of gas areas to district heating, as well as the four subsidy pools for phasing out oil and gas boilers, as with the Finance Act for 2021 has been allocated several funds: the Building Pool, the Scrapping Scheme, the District Heating Pool and the Disconnection Scheme.

The development of energy consumption in the households are determined by a number of factors, such as choice of heating, size of household, and the general condition and age of the households. The development is generally expected to move towards more collective district heating, thus fewer individual types of heating. In 2020, little more than half of households had district heating as the primary heating type, and in 2030 the number is expected to reach 65 percent, continuing to rise even further thereafter.

Regarding individual types of heating, the overall expectation is that there will be a rise in the number of heat pumps, and a fall in number of households being heated by oil boilers, gas boilers, biomass boilers and solar panels (Elpaneler). In 2020, heat pumps constituted 8 percent of the type of heating in households, and this number is expected to rise to 14 percent in 2030, and 20 percent in 2035. Gas boilers and oil boilers were the primary type of heating for respectively 21 percent and 4 percent in the household buildings in 2020, and this number is expected to fall to respectively 10 percent and 1 percent by 2030.

The most recent estimate for 2030 from the Danish Energy Agency is that by then approximately 185000 household buildings will have oil or gas boilers as primary heating source, while 260000 household buildings will have heat pumps, and approximately 1.2 million buildings will be connected to the collective district heating and have that as primary heating source (DEA 2022:25). It is worth noting that these estimates are based on fuel prices from December 2021, before the war in Ukraine, adding a lot of uncertainty to the estimates.

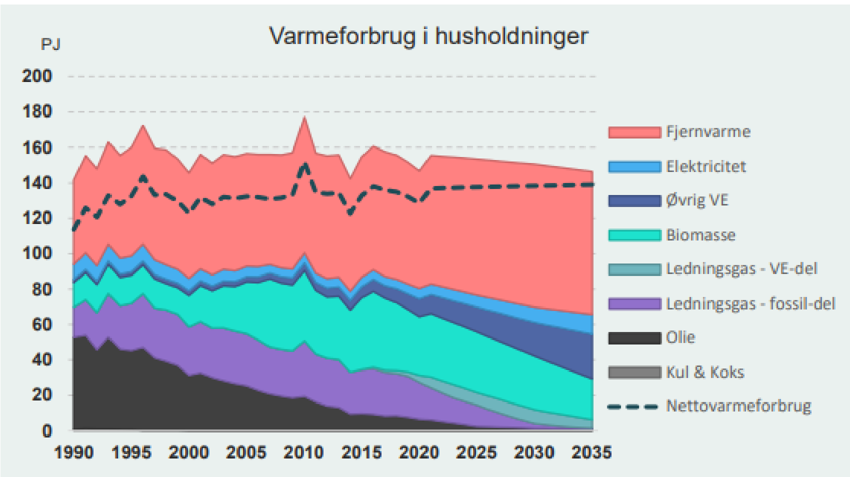


Figure 8-4: Heat consumption in households

66% of all households are supplied with district heating. The figure above shows that the heating of households is generally expected to be covered more and more by district heating ("Fjernvarme").

For the individual heating types, the gas and oil-based heating is experiencing a reduction, and while biomass is also reduced, it is still expected to constitute 20 percent of the total heating consumption in 2030. Other heating energy ("Øvrig VE") consists primarily of heat pumps and solar energy, and this constitutes 6 percent in 2019 with an expected rise to 13 percent in 2030. (DEA 2022:25)

Besides heating, the Danish households are also using energy in the form of electricity for lighting and appliances. The figure below shows that the electricity consumption for lighting and appliances in households rose by 19 percent from 1990 until 2020. The local peak around 2020 could be due to working from home during the COVID-19 pandemic, and the consumption is expected to fall thereafter (DEA 2022:26).

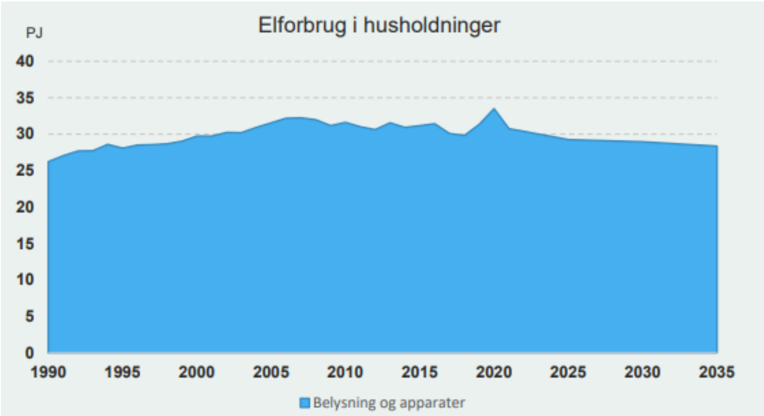


Figure 8-5: Electricity consumption in households

Though there is a lot of support in the Danish population for the implementation of renewable energy, often people express that they do not want the interventions "in their own backyard". According to the Danish Ministry of Climate, Energy and Utilities, more than a third of the population are against having e.g., windmills and biogas facilities placed near their homes. This discrepancy between a general positive attitude towards the green transition and the "not in my backyard"-syndrome can definitely be viewed as a barrier to the implementation of renewable energy interventions in Denmark (Norstat on behalf of the Danish Ministry of Climate, Energy and Utilities, 2019: Q8B[110].)

> *Q8B: "To what degree do you agree in the following statement: "I am reluctant towards placement of e.g. windmills or biogas facilities near my home"?*
>
> *Strongly agree: 12%*
> *Agree: 22%*
>
> *Neither agree nor disagree: 37%*
> *Disagree: 22%*
>
> *Strongly disagree: 8%*

According to CONCITO, Denmark's leading climate think tank, a lack of information and knowledge constitutes a substantial barrier to the energy renewal of buildings, especially in the private sector. The biggest motivation to carry out energy renewals/adaptations for private homeowners is often not

[110] https://kefm.dk/media/6502/resultat-af-survey-om-danskernes-holdning-til-klimadilemmaer.pdf

the climate alone, but the fulfillment of other comfort and health related needs (Source: CONCITO, 2021[111]).

According to The Danish Construction Federation, 8% of house owners think that the condition of their home is bad when it comes to energy. The actual number is much higher; 34% of the homes are labelled E or worse. This indicates that Danish homeowners think that their homes are in better condition than they actually are, again indicating an important knowledge gap/barrier.[112]

More than a third of homeowners find it attractive to invest in at least one type of renewable energy for their house. Especially PV, solar heating, and heat pumps. 42% do not have an interest in investing, either because they already have renewable energy sources installed, or because the initial investment is too big. The numbers behind this study show that approximately 25% of the homeowners already have a renewable energy facility connected to their home.

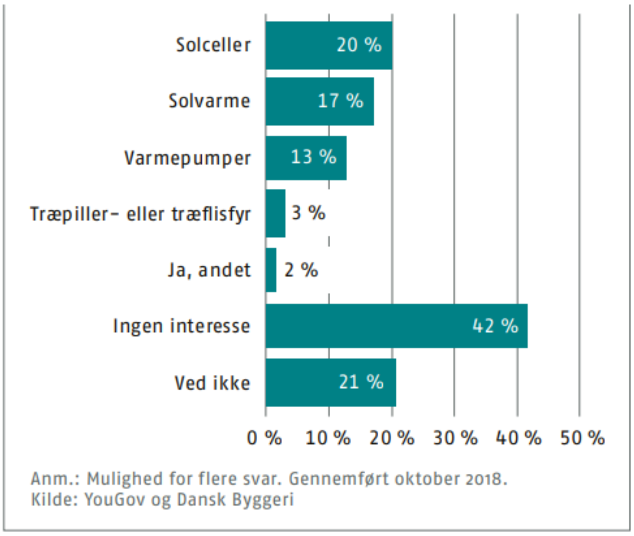


Figure 8-6: Interest in investing in a renewable energy system for the home, 2018[113]

The biggest barriers for investing in renewable energy is, according to a survey carried out by The Danish Construction Federation, that it's too big of an investment (24%). 16% think there is a big amount of uncertainty regardig the economic terms of the investment, while 10% think that their building or land plot is not physically suited for a renewable energy facility. 14% do not experience any major barriers.

The effects of energy renovations are the highest in buildings, where the inhabitants cannot afford to properly heat their home, also known as being "energy poor". In Denmark, 3% of the population is energy poor (the EU28 average is 7.4%) (Source: Danish Energy Agency). [114]

[111] "The role of buildings in the fight for the climate". https://concito.dk/files/media/document/Notat%20Bygningers%20rolle%20i%20klimakampen%20%20%282%29.pdf

[112] https://www.danskindustri.dk/siteassets/di-byggeri/analyse-og-politik/klima-energi-og-baredygtighed/baredygtighed/baredygtig-energi/klausuleret-byggeriets-energianalyse_2019_samlet.pdf p18.

[113] https://www.danskindustri.dk/siteassets/di-byggeri/analyse-og-politik/klima-energi-og-baredygtighed/baredygtighed/baredygtig-energi/klausuleret-byggeriets-energianalyse_2019_samlet.pdf p45.

[114] https://ens.dk/sites/ens.dk/files/Energibesparelser/afledte_effekter_ved_energirenovering_ea_energianalyse_2019.pdf

Unfortunately, the low-income energy poor families often cannot afford taking actions to lower their energy consumption, because the initial investment is too big.

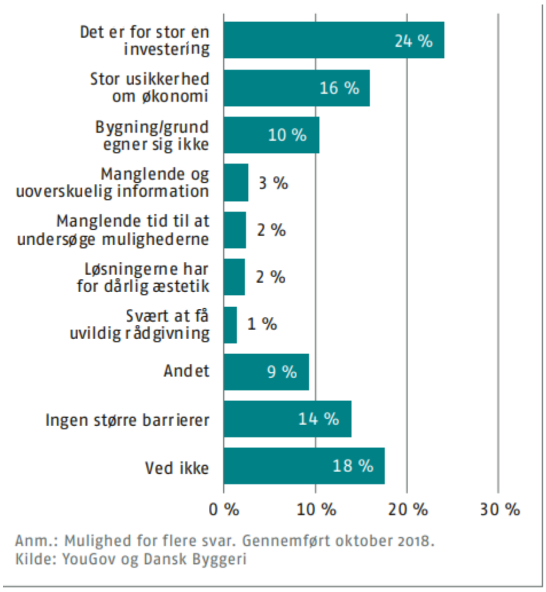


Figure 8-7: Barriers for investing in renewable energy. (Source: The Confederation of Danish Industry[115], 2019)

There is an issue regarding the incentives for energy renewals in rental properties owned by private owners. The paradox of the property owner paying for the energy renewal, while the renter is the one benefitting of the savings (split incentive), has often been mentioned as a barrier for energy renewals. This is mitigated by having legislation in place securing that the rent can be raised after an energy renewal, making the renewal a good deal for both renter and landlord.

There seems to be a difference between rental units owned by bigger (professional) companies/organizations and small private landlords. According to The Danish Association of Construction Clients, for the small private landlords getting an overview of the energy renewal is a challenge and often results in them giving up and opting out of a renewal, because the gain is not clear, or the administration is too difficult to navigate. An action taken to mitigate this is the ProjectZero which has built an instruction/guidance tool which can be used for creating overview, understand and translate into actions. The tool is called "Udlejerenergi.dk" (source: Bygherreforeningen (The Danish Association of Construction Clients)).[116] [117]

According to the latest "Energy Analysis" (2019) from The Danish Construction Federation there is a slight overrepresentation of residential buildings amongst buildings with the lowest energy labelling scores[118].

[115] klausuleret-byggeriets-energianalyse_2019_samlet.pdf (danskindustri.dk)
[116] https://bygherreforeningen.dk/energirenovering-giver-vaerdi-for-lejer-og-udlejer/
[117] https://udlejerenergi.dk/
[118] https://www.danskindustri.dk/siteassets/di-byggeri/analyse-og-politik/klima-energi-og-baredygtighed/baredygtighed/baredygtig-energi/klausuleret-byggeriets-energianalyse_2019_samlet.pdf p18

1.1.1 Offices

There is not any general trend to describe this market segment; no national strategy or scheme supporting energy green offices.

As for sustainability certifications for offices, many of new buildings are DGNB certified which can lead to higher rental price. It is becoming more common for clients to demand some level of DGNB certification for the building. Common sustainability measures that are taken include complying with DGNB requirements. Compliance is not difficult to achieve as there are many ways to obtain the points needed to comply with the lowest level of DGNB.

Regarding renovation of offices, building owners are becoming more interested in taking sustainability measures since it is one of the driving factors for the increase of rent.

1.1.2 Public

Denmark has a relatively large public sector, covering kindergartens, schools, hospitals, and the public administration. Municipalities often host information events about energy renewal and sustainable energy, often in relation to implementation of new (political) strategies or in connection to concrete renewal projects. In general, the Danish municipalities hold the view that input of the citizens are of the utmost importance since it heightens the trust towards the authorities and the feeling of being heard. Many municipalities therefore have digital mailboxes, workshops, and the like set up in order to systematically gather input, comments, ideas etc.

According to the Technical University of Denmark (DTU), the most common energy renewals of the Danish public school during the last 10 years are: façade and roof 21%; windows/sun reflecting 18%; ventilation 18%; lighting 14%; heating system 10%; renewable energy 6%; acoustics 4%; total renovation 2%; other 7%[119]. Besides the lowered carbon emissions, an important side effect of energy renovations in healthcare buildings and schools is the improved indoor climate, creating optimal conditions for respectively healing and learning.

119 https://ens.dk/sites/ens.dk/files/Energibesparelser/afledte_effekter_ved_energirenovering_ea_energianalyse_2019.pdf page 35

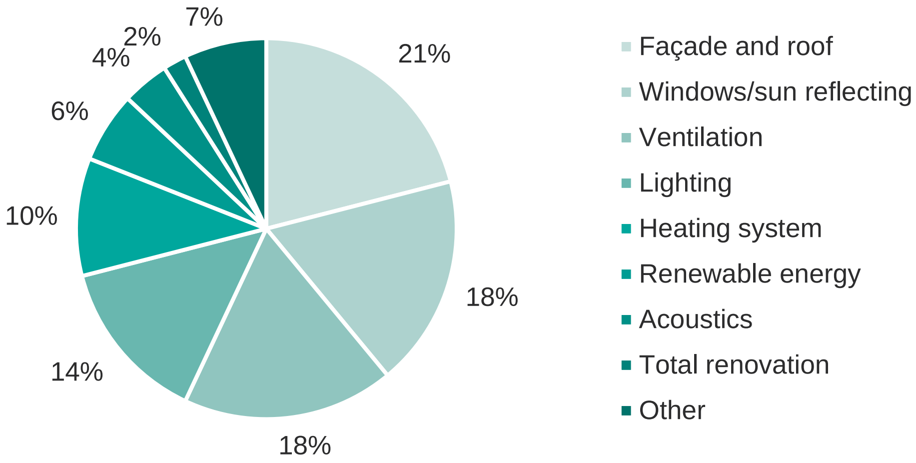


Figure 8-8: Most common energy renewals of Danish public schools over the last 10 years

A barrier when it comes to energy renovations of both schools and healthcare buildings is the relocation of the users of the building while the renovation is ongoing. Temporary solutions are often far from ideal, especially if the project is stretching beyond the summer months, as the Danish climate is not exactly known to be stable and/or friendly.

The Danish Energy Foundation through InnoBYG, the innovation network of the construction sector for sustainable building 2010-2020, created the "Roadmap for buildings' role in the green transition", containing a number of recommendations and guidelines supporting the road towards a fossil fuel free society[120] [121].

Denmark has a relatively large public sector, covering kindergartens, schools, hospitals, and the public administration.

The majority of the combined sectors energy consumption stems from electricity and district heating. Transport is also not accounted for in this section and is not accounted for in this appendix either (DEA 2022:35).

Energy consumption

The service sector uses 13 percent of the total energy consumption of Denmark, which is expected to rise to 20 percent in 2035. There is an expected rise in the total energy consumption from 80 PJ in 2019 to 125 PJ in 2035. The cause for the rise is mainly the creation of data centers (from 1 PJ in 2019 to 27 PJ in 2030 and 35 PJ in 2035).

When it comes to the public sector, all services within kindergartens, schools and hospitals use a substantial amount of electricity. Use of electricity for heat pumps is expected to rise.

In 2019, electricity constituted 45 percent of the sector's total energy consumption, and this number is expected to rise to 63 percent by 2035. According to this projection the service sector will then be responsible for more than 40 percent of the total electricity consumption in 2035.

The sectors' consumption of fossil fuels is mainly consisting of gas ("Ledningsgas" = "piped gas"), but this is expected to be reduced from 9 PJ in 2020 to 3 PJ in 2035. This reduction is mainly because of

[120] https://www.innobyg.dk/media/75132/roadmap-rapport_final.pdf

[121] http://energifonden.net/#

converting from gas boilers to heat pumps. However, this projection comes with uncertainties as the war in Ukraine has accelerated the conversion dramatically (DEA 2022:37).

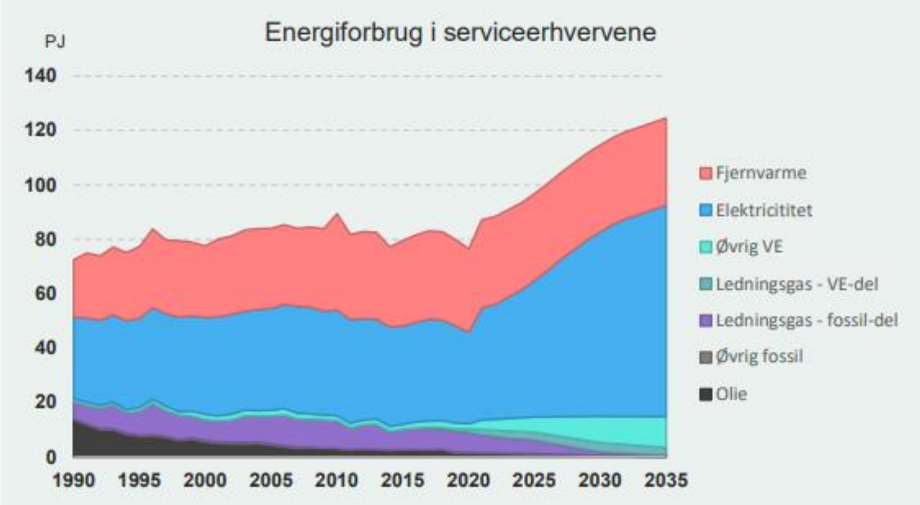


Figure 8-9: Energy consumption in service sector

Public-private partnerships: Strategic energy planning at municipal and regional level

In Denmark, it is not uncommon for stakeholders within the energy sector to enter into public-private partnerships, very often on municipal or regional level. *"The Danish government's long-term vision is that Denmark becomes independent of fossil fuels. Municipalities have the local knowledge that can ensure political anchoring and commitment from citizens and local businesses to the green transition of the energy system and the economy. In their capacity as local planning and land-use authority, as owner of supply and transport companies, and as a major consumer, the municipalities are in a unique position to facilitate change."* (DEA 2015:2[122])

The government is acknowledging that change comes through collaboration, and these collaborations and partnerships happen on municipal level, in some way or another. Therefore, the government launched a program with 3.3 million euro in 2014 to support strategic energy planning on the municipal level, strengthening partnerships both vertically (state, region, municipality), horizontally (across municipalities), locally (businesses, supply companies, municipality), internally (municipal administrations) and democratically (citizens and interest organizations) (DEA 2015:2). *"Municipalities in Denmark have a number of mandatory duties related to heat planning and physical planning for wind power plants and biogas facilities. Strategic energy planning, however, is voluntary but almost all municipalities have chosen to develop such plans."* (DEA 2015:3).

The publication by the Danish Energy Agency (DEA) **"Strategic energy planning in Denmark at municipal and regional level"** gives an account for 14 of these partnerships, carried out in 2014-2015:

1) **Energetic Northern Jutland.** Regional partnership encompassing the 9 municipalities and the regional administration, exploring how strategic energy planning can retain and create jobs in the region, to show that it is possible to create an interconnected flexible energy system based on renewable energy, and to illustrate the impact that the green transition has on the possibilities for business development (DEA 2015:4).

[122] DEA 2015: "Strategic Energy Planning in Denmark at Municipal and Regional Level", Danish Energy Agency.https://www.eaenergianalyse.dk/wpcontent/uploads/2020/02/1414_strategic_energy_planning_denmark.pdf

2) **Strategic Energy Clusters in Central Jutland**. Common strategy to reach a target of 50% renewable energy in 2025 developed by all municipalities, energy companies, universities and other relevant actors. (DEA 2015:4)
3) **Strategic Energy Planning Communicated.** Cooperation between 22 municipalities, 3 energy companies, Clean Energy Cluster, led by the Region of Southern Denmark. Focus on social dynamics, anthropological approach, what drives and motivates consumers to make the energy technology choices that they do? Special focus on summerhouse areas and villages. (DEA 2015:5)
4) **Strategic Energy Plan Funen.** *"Funen is characterised by a high share of agriculture, with remarkable biomass resources, and well-developed district heating and gas distribution systems. To ensure the success and stability of future local investments in the energy sector, Funen has developed a political framework for the future energy investments – an energy plan. The plan was developed in a broad cooperation between 9 municipalities on Funen and Ærø, 5 supply companies, the University of Southern Denmark (SDU), Centrovice (the local agricultural trade organisation), and Udvikling Fyn (a regional trade development company)."* (DEA 2015:5) [123]
5) **Energy Planning of the Future in the Capital Region**. The project 'Energi på Tværs' has connected all municipalities and larger utility companies within the Capital Region of Denmark, to develop analysis, visions, and strategies to support the transition to a fossil free future and to open up for new cross-sectorial collaboration. Objective to become fossil free by 2050. (DEA 2015:6). [124]
6) **Region Zealand (Steps).** Strategic energy planning across 16 municipalities in Region Zealand, 19 supply companies. Create basis for policy decisions and ensure cooperation across municipal borders. Three new cooperation projects: "Biogas2020", "Implementation of Bioenergy Zealand" and "Wind power as a catalyst for local development". (DEA 2015:6).
7) **Billund Least Cost Energy Action Plan**. "Green industrial symbiosis" exploring the potentials for one industrial company's waste becoming a resource for another company. (DEA 2015:7) [125]
8) **Grenaa City Energy Supply Strategy**. Partnership with multiple private companies. (DEA 2015:7).
9) **Bornholm – Bright Green Island**. "Even though Bornholm is a small rural island in the middle of the Baltic Sea, or perhaps because of this, Bornholm is the center of developing and testing the energy solutions of tomorrow. With approx. 40,000 inhabitants Bornholm is a full-scale community, with hospital, courthouse, schools, industry, ferries and airport. Bornholm has an operating energy system integrating electricity production, wind turbines, biogas, waste, solar panels, solar cells, heat pumps and district heating." In 2008, the Municipality of Bornholm decided on a vision that Bornholm should become a carbon neutral community in 2025 (DEA 2015:8). [126]
10) **Steps Business**. "In STEPS Business, 8 municipalities in Region Zealand, joined forces in mapping local businesses with energy efficiency potential and the opportunities for creating a win-win situation between the strategic energy targets and local businesses. The project

[123] More info at http://www.energiplanfyn.dk/
[124] More info at https://www.gate21.dk/energi-paa-tvaers/
[125] More info at https://www.billundbiorefinery.com/
[126] https://www.youtube.com/watch?v=p7084JiuiMU

was headed by Energy Cluster Zealand, a non-profit organisation, established in 2009 with the purpose of coordinating strategic energy efforts within Region Zealand." (DEA 2015:8)

11) **Strategic Energy Planning in Remote Areas**. Strategic partnership, four municipalities reached out with assistance to citizens in the 60+ segment to educate them on how to increase the comfort level and energy efficiency of their homes. (DEA 20159).
12) **Increased Flexibility in Local Energy Systems**. Corporation between two municipalities in different parts of the country, aiming at engaging heating companies, ensuring "a higher buy-in from the energy companies in the overall energy strategy for the municipality before focusing on implementing technological solutions". (DEA 2015:9).
13) **Ærø Smart Energy Island**. "Ærø with a population of 6,200 has since the 1980s embarked on sustainable transition. The energy vision is to become carbon neutral and self-sufficient with renewable energy by 2025" […] "Analyses carried out in relation to the project 'Smart Energy Island' investigates how Ærø can become fossil free." Additionally, together with the Danish Maritime Authority and eight other partners, Ærø Municipality has launched project 'E-ferry', supported by EU H2020 programme, demonstrating "a 100% electric, medium sized ferry for passengers and cars, trucks and cargo1 in fullscale operation on longer distances than previously seen (> 5 nautical miles) for electric drive train ferries." (DEA 2015:10).
14) **Cost-Effective Accelerated Green Transition in Høje Taastrup**. Høje-Taastrup Municipality has analysed the options for heat storage, district cooling, and cross-municipal supply as part of their Strategic Energy and Climate Plan 2020 (DEA 2015:10).

Other examples of more recent municipal/regional public-private partnerships are:

- **Smart City Accelerator+.** Funded by the EU InterReg ØKS funding scheme, working to develop and test methods for making heat and electricity production more climate friendly, and making the usage of energy in buildings as efficient as possible, while at the same time addressing and including the citizens [127].
- **Sol over byen ("Sun over the City").** Creating energy communities and exploring the social and management related advantages obtained by developing local energy communities in local areas of Copenhagen. The project has worked with a dual scope of examining both the perspectives of the citizens/social perspective and that of the government/municipality/management perspective [128].

[127] https://smartcitiesaccelerator.eu/
[128] (https://kk.sites.itera.dk/apps/kk_pub2/pdf/2320_7be14b5d53c9.pdf)

8.2 Building codes and regulations

National energy strategy for 2050

"The main goal of the Danish 2050 Energy Strategy is to achieve 100% independence from fossil fuel in the national energy mix by 2050. In a first step to completely phase out fossil fuels, the government targets the drop in the consumption of oil, gas and coal by 33% between 2009 and 2020. The share of thermal production in total energy generation should also decrease from 71% to 40% over the same period. To reach 100% of electricity from renewable, the Danish government greatly focuses on wind energy, expected to provide for 40% of total electricity needs, together with biomass and biogas. A solid district heating network, fed by renewable heat from biomass, will be the main motor of the energy transition in the heating sector. Full independence from fossil fuels will also be reached through a solid and long-term energy efficiency policy aiming at reducing gross energy consumption by 6% from 2006 levels. Energy companies will be required to increase energy savings by 50% in 2013 and 75% by 2017 to 2020. Electric meters diffusion will participate in monitoring energy demand in the residential sector. In the building sector, the Danish government is going a step forward in implementing very ambitious building code, banning oil boilers in all new constructions and, by 2017, in all houses while biomass, biogas and solar thermal appliances will be strongly encouraged. Denmark also targets the large-scale deployment of offshore wind as well as dramatic growth in the wind manufacturing sector, and will fund research and development in for solar and wave power, support main demonstration projects for large heat pumps intended to be used in district heating plants and fund other geothermal energy research projects. In order to generate revenues to finance the energy shift of the country, Denmark will introduce a public service obligation tax on electricity and gas, while tax on oil, gas and coal will be further increased to discourage their use. With regards to nuclear, the country has maintained its ban on nuclear power program and, since there is no potential for large hydropower project, most of the funding will be dedicated to new renewable sources." [129]

Framework[130]	Area	Obligation/target
Government platform 2015	Phase-out of fossil fuels	Denmark is to be climate neutral by 2050
Danish climate law	Low emission society by 2050	Target is not specified
EU: 2020 targets	Greenhouse gas emissions from buildings, agriculture, and transportation	To be reduced by 20 pct. Between 2005 and 2020
	Fraction of renewable energy in total energy consumption	30 pct. By 2020
	Fraction of renewable energy in transport sector	10 pct. By 2020
EU 2030 targets	The total emissions from the EU are to be reduced by 40 pct, between 1990 and 2030. This includes the following targets for the EU as a whole: 43 pct reductions from large emitters such as power plants and the oil and gas sectors.	The emission reduction targets for the EU as a whole are to be implemented as national reduction obligations for buildings, agriculture and transportation. The Danish

[129] https://www.iea.org/policies/5122-energy-strategy-2050

[130] https://byudvikling.kk.dk/klimaplanhttps://bettergreen.dk/livscyklusvurdering-lca-og-baeredygtigt-byggeri

	30 pct reductions of emissions from buildings, agriculture and transportation. At least 27 pct renewable energy in total energy consumption by 2030. At least 27 pct increase in energy efficiency by 2030	reduction obligations have not yet been negotiated.

Table 8-1: Overview of various targets and obligations (Source: https://ens.dk/en/our-responsibilities/energy-climate-politics/danish-climate-policies)

8.2.1 General building code: Bygningsreglementet 2018

The current building code of Denmark is Bygningsreglementet 2018[131] which contains requirements for both new buildings and for renovations, and often receives minor updates. New buildings must live up to BR18. Existing buildings being renovated must comply with the component requirements in the building code.

A new building code is expected in 2023. The new code in 2023 will require new buildings above 1000 m^2 to emit less than 12 kg CO2eq/m^2/year. This is the first time that this type of requirement is part of the building code.

BR18 lists the various requirements for access, architecture, energy, fire, structures, MEP etc. The building code lists specific requirements, but also refers to various Danish Standards (DS), that list all the requirements for a given discipline. Danish Standard is in general viewed as the standard that needs to be followed to comply with the building code in Denmark. The Danish Building Research Institute (SBi) have created numerous guidelines on various subjects. These are often viewed as good practice, and most of the standards are based on this work. They are more comprehensive than the DS standards.

In Denmark the municipalities used to approve all building permits. To make it more efficient, and as projects became more complex, the approval of structures and fire was removed from the municipality. Today a certified structural engineer and certified fire engineer is needed, to start the application for a building permit.

Most of the standards in Denmark relating to performance of equipment, e.g., heat pumps, are EN standards converted to the Danish market, e.g., DS/EN14511.

Some clauses of the BR18 are explained below:

- §259 Energy framework for residence, student housing, hotels and the like: For residence, student housing, hotels and the like the building's combined need for energy for heating, ventilation, cooling and hot water per m2 heated area must not exceed 30,0 kWh/m2 per year plus 1,000 kWh per year divided by the heated area.
- §260 Energy framework for other buildings than residential: For other buildings than residential, which are not included in §259, the building's total need for energy for heating, ventilation, cooling, hot water and lighting per m2 heated area does not exceed 41,0 kWh/m2 per year plus 1,000 kWh per year divided by the heated area.
- § 274 - § 279 Energy requirements for conversions and replacement of building parts

[131] https://bygningsreglementet.dk/Tekniske-bestemmelser/11/Krav [131] https://bygningsreglementet.dk/Tekniske-bestemmelser/11/Krav[131] https://bygningsreglementet.dk/Tekniske-bestemmelser/11/Krav

- §274 In the case of conversions, energy savings must be carried out to the extent that they are profitable and do not entail a risk of moisture damage. The energy requirements for conversion can either be met by complying with the requirements for all affected building parts in § 279 or by following the renovation classes for existing buildings in §§ 280-282. The renovation classes are an energy framework for existing buildings.
- §275 Conversions where annual savings times lifetime divided by investment is greater than 1.33 are profitable. In the event that conversions are not profitable, a verification of the lack of profitability must be carried out. In the event that a conversion is not profitable, it must be investigated whether a smaller conversion is profitable.
- §275.2 In constructions with cavities with space for insulation, such as e.g., raised roofs with rafters, it must first be investigated whether insulation in the cavities is profitable, and then whether it is profitable to subsequently insulate up to the requirements of § 279.
- §276 Building changes that involve increased energy consumption can be carried out if corresponding compensatory energy savings are carried out.
- §293-§298 Heating of buildings
- §293 Building heating must be based on renewable energy
- §294 In buildings located in areas where connection to the district heating network is possible, building heating can be based on district heating regardless of § 293.
- §295 In buildings located in areas where a natural gas network has been established, or where there is a project approval drawn up before 1 January 2013 for individual natural gas supply to the area in accordance with the Heating Supply Act, building heating can be based on natural gas regardless of section 293.
- §296 Existing buildings located in areas where connection to the district heating network is not possible, or where a natural gas network has not been established or a decision made in accordance with the Heating Supply Act before 1 January 2013, cf. § 295, are not covered by § 293.

8.2.2 Energy requirements of buildings

New buildings in Denmark have to comply with an Energy Frame Calculation. The requirements are set out in BR18, and a tool named Be18, developed by SBi, has to be used. The energy requirements depend on the type of building and the size of the building. Most buildings require PV installed to comply with the strict requirements of the Energy Frame.

8.2.3 Refrigerants

For refrigerants, Denmark follows F-gas directive, but there are country specific requirements, eg. Maximum of 5-ton GWP equivalent of the cooling system[132].

8.2.4 Photo Voltaic

The business case for PV on buildings in Denmark often depends on the use of the building. Typically, in Denmark each tenant of a building pays their own energy bill and have their own meter in their switch board. Due to this, the PV installation is typically connected to the switchboard that provides electricity to common/shared areas. Depending on the building, this is typically only a fraction of the energy used.

[132] https://www.retsinformation.dk/eli/lta/2021/1013

To avoid selling the electricity at market value, the electricity needs to be used within the same hour it has been produced. If this is not the case, the electricity is sold to the market. Before the energy crisis, the price of electricity only accounted for roughly 25 % of the total price. It is therefore beneficial to be able to use the electricity yourself, rather than selling it.

In 2012, there was a rapid rise in the installation of PV due to some very lucrative subsidy schemes. Since then, the growth has stagnated a bit, though it's still on the rise.

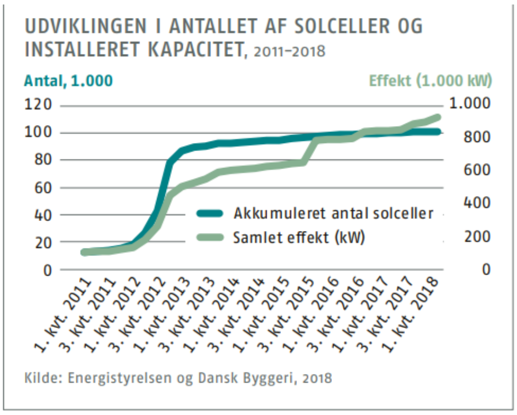


Figure 8-10: Number of PV installations over time. (Source: The Confederation of Danish Industry[133], 2019)

If a house is equipped with PV, the surplus electricity can be sold to the grid, if there is an agreement with an electricity company. Tariffs vary. Also, depending on the location, the PVs can be regulated due to aesthetics and also if the grid is able to handle the load.

Using PV in projects where the building has multiple tenants can be tricky. When there are multiple tenants, they typically have their own electricity metering. For projects with multiple tenants, the PV is typically only used for "Shared" areas, and the rest is sold back to the grid. Before the energy crisis, this was not a good investment, but they were typically put up due to the need from the energy frame requirements.

8.2.5 Heat Pumps

Generally, all sorts of renewable energy are promoted in Denmark. This includes heat pumps, especially outside of areas with available district heating. The heat pumps must live up to the building code and follow the European F-gas regulation.

There are two ways of getting a heat pump; buying and owning it or getting it on subscription. In the long run, it is economically most viable to buy and own the heat pump.

There are subsidies available for buying and owning heat pumps, in case of living in an area without district heating availability, but only for heat pumps with an energy label of A++ or A+++. Size of subsidy amounts to 13-30,000 DKK, if changing from natural gas, oil, electric heating, or bio-boilers. A heat pump for a one family home typically costs 90-120,000 DKK (including installation). In case of choosing to get a heat pump subscription, a one-time subscription fee is paid, a monthly subscription

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[133] https://www.danskindustri.dk/siteassets/di-byggeri/analyse-og-politik/klima-energi-og-baredygtighed/baredygtighed/baredygtig-energi/klausuleret-byggeriets-energianalyse_2019_samlet.pdf p44).

fee, and the consumption. This is more costly in the long run, but the initial investment is smaller, and there is no need for the user to learn everything about the technology, regulations etc., since there is a supplier with this responsibility.

Use of heat pumps is not mandatory in Denmark. Oil boilers are illegal to put up and Denmark is trending away to use gas fired boilers.

8.2.6 Geothermal

According to the Danish Construction Federation there are a lot of potential for installation of solar power panels, solar heating, heat pumps and even household windmills in the Danish building mass. The interest from Danish homeowners is big, but for many people the initial investment is deemed too big which is a clear barrier to the green transition[134].

8.2.7 Compliance with energy frame calculation

Since 2006, in the case of new buildings and when changing the use of an existing building, it has to be complied with an energy frame calculation. If major remodeling is being done, new requirements have to be complied with, unless showing proof that the payback time is too great.

8.2.8 "Craftsman Deduction"

The most well-known initiative supporting private (energy) renovations in Denmark is the "Håndværkerfradraget" ("Craftsman Deduction"), which is a tax deduction scheme where homeowners can get a tax deduction on (energy) renovations of their homes. This scheme ended in 2022.

8.2.9 Support schemes

There are a number of current funding pools and support schemes relating to energy renovations and renewable energy in different sectors in Denmark. The most important ones are:

- Bygningspuljen – The Building Pool: Making it possible for private homeowners, owners' associations, public housing associations, student housing associations, landlords etc. to apply for subsidy for energy renovations[135].
- Subsidy for energy renovations and digital solutions in municipal and regional buildings[136].
- Afkoblingsordningen – The Decoupling Arrangement: Covering costs for private homeowners to decouple from gas for heating[137].
- Subsidy for heat pumps[138].
- District heating pool, subsidizing utility companies to expand the district heating network[139].
- Ordning for geotermi – Arragement for Geothermics: Subsidy for risk assessments in relation to geothermic drilling[140].

[134] https://www.danskindustri.dk/siteassets/di-byggeri/analyse-og-politik/klima-energi-og-baredygtighed/baredygtighed/baredygtig-energi/klausuleret-byggeriets-energianalyse_2019_samlet.pdf p43
[135] https://ens.dk/service/tilskuds-stoetteordninger/bygningspuljen
[136] https://sparenergi.dk/offentlig/vaerktojer/tilskud
[137] https://ens.dk/service/tilskuds-stoetteordninger/afkoblingsordningen.
[138] https://ens.dk/service/tilskuds-stoetteordninger/skrotningsordningen.
[139] https://ens.dk/service/tilskuds-stoetteordninger/fjernvarmepuljen
[140] https://ens.dk/ansvarsomraader/geotermi/ordning-geotermi

- Erhvervspuljen til energispareprojekter – Pool for energy saving projects in the trades, where companies can get up to 50% subsidy in their energy renovations[141].

8.2.10 Funding for public buildings

Public buildings account for 6% of the total building mass in Denmark. Of these 6% municipal buildings account for 74%. Therefore, there is a great need to focus on the municipality owned buildings, and this is done e.g. via funding schemes. In 2018 the Energy Deal established a funding pool (loan) of 100 mil. DKK pro anno in 2021-2024 earmarked for energy renovations of buildings owned by municipalities and/or regions. Normally energy renovations are covered by the regular municipal construction framework, and this framework can sometimes be a barrier for investments in energy renovation projects. However, the funding pool of the 2018 Energy Deal is set up outside of the regular municipal construction framework[142].

In 2021 and 2022, the Danish government created a subsidy fund with 295 million DKK (approx. 40 million EUR) to be spend by municipalities and regions on energy renovation projects. Through the funding scheme the municipality or region can get subsidized with 30% of the project cost (though max 5 million DKK per public entity). The money can be spent on concrete energy renovations such as new windows or conversion to heat pump, but can also be granted to digital projects, e.g. software solutions monitoring and optimizing the energy usage in public buildings, or for educational efforts regarding energy efficient operations. The subsidy fund is focused on providing funds to projects in buildings with an energy label rating of D, E, F or G, securing the highest possible savings in energy usage (Danish Energy Agency).

8.3 Energy market rules and tariffs

8.3.1 Electricity and district heating

Introduction

In the Climate and Status Outlook from the Danish Energy Agency, the electricity and district heating sector are constituted by the facilities supplying the Danish society with electricity and district heating, though excluding waste burning facilities which is treated separately in the publication. The sector includes facilities such as power-and-heating plants (producing both electricity and district heating), wind power plants and solar power plants producing electricity, and solar plants and heat pumps producing district heating. The electricity and district heating sector (still excluding waste burning facilities) emitted 3.9 million tons CO2e in 2020, equivalent to 9 percent of Denmark's total emissions. This number is expected to fall to 1.3 million tons (3 percent) in 2025, 0.3 million tons (0.8 percent) in 2030, and 0.15 million tons (0.5 percent) in 2035. This development is due to a number of things, e.g., phasing out of the last coal burning power plants, continuous investments in wind and solar energy, an extensive increase in use of heat pumps for the production of district heating and a reduction in power and heat production based on piped gas ("ledningsgas"). (DEA 2022:49).

[141] https://ens.dk/ansvarsomraader/energibesparelser/virksomheder/erhvervstilskud-til-energieffektiviseringer

[142] https://www.danskindustri.dk/siteassets/di-byggeri/analyse-og-politik/klima-energi-og-baredygtighed/baredygtighed/baredygtig-energi/klausuleret-byggeriets-energianalyse_2019_samlet.pdf p25).

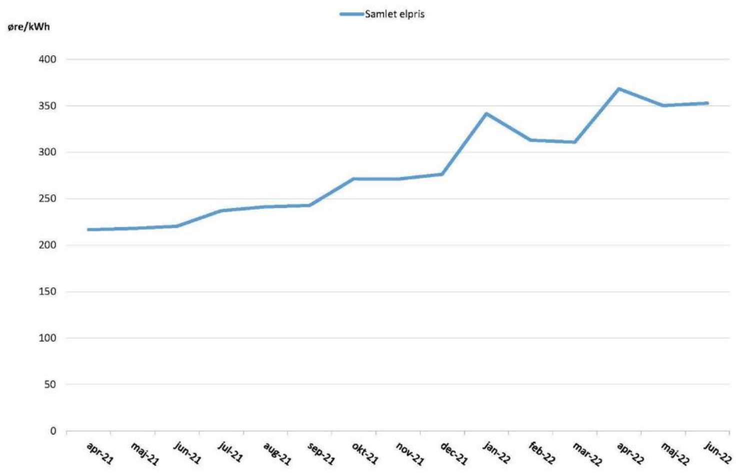


Figure 8-11: Electricity prices. Source: https://forsyningstilsynet.dk/tal-fakta/priser/elpriser

Energy consumption

The figure below shows the development of the electricity and district heating sector. The development is characterized by an extensive transition towards sustainable energy. On the whole, the consumption of fossil fuels is expected to decrease dramatically, with 50 percent, 87 percent and 90 percent in respectively 2025, 2030, and 2035, compared with the consumption in 2020. The future Danish electricity production will be based on primarily solar and wind energy, and the rest of the production of electricity and district heating will mainly be based on burning of biomass (DEA 2022:51).

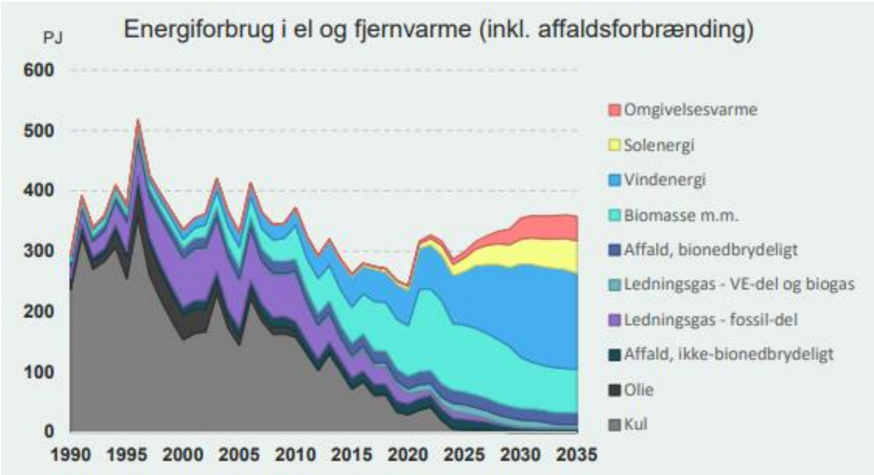


Figure 8-12: energy consumption in electricity and district heating incl. waste incineration

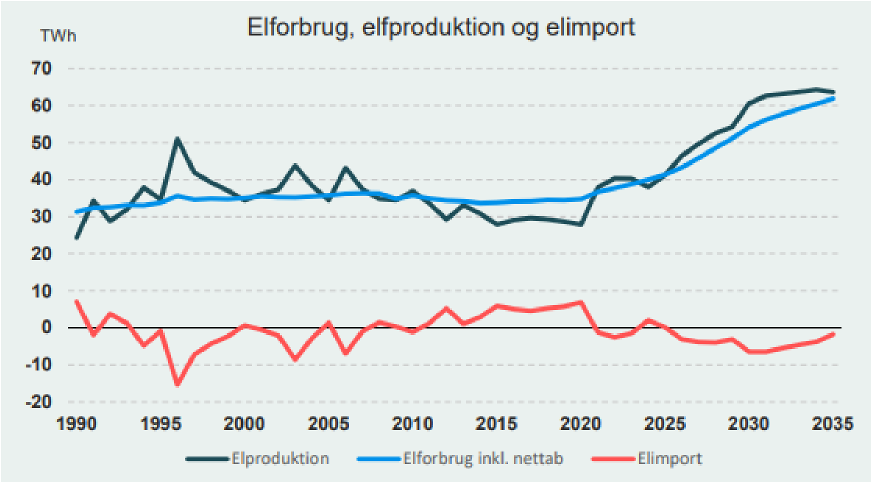


*Figure 8-13: * Elproduktion = Electricity production. Elforbrug inkl. Nettab = Electricity consumption including net loss. Elimport = Electricity import.*

The Danish electricity system is strongly integrated into the north European market. The balance between production within Danish borders (domestic production) and the import from other countries fluctuates quite a bit depending on the market conditions, which again are depending on weather conditions (rain, temperature, wind).

Taking the creation of the Danish "Energy Islands"[143] into account, the Danish Energy Agency expects that the domestic production will exceed the domestic energy consumption. This of course comes with some uncertainties, e.g., in connection to the production side which is again made uncertain due to shortages in materials and the like, and in connection to the consumption side (e.g., in relation to the creation of new data centers with a high consumption).

Combined with the uncertainties created by variations in the weather, the Danish Energy Agency thus expects that there will be years of net import and years of net export of electricity. However, overall the energy islands are expected to have a substantial effect in a positive direction, creating a surplus of sustainable, green electricity (DEA 2022:52).

Due to the fluctuations in the energy supply, the Danish Energy Agency foresees a challenge in securing that the rising consumption continues to be covered by sustainable energy sources. Furthermore, there is a challenge of matching the production with the consumption at all times – a challenge which must be solved in cooperation with the involved sectors, e.g., through enhanced flexibility on the consumption side. Thus, the composition of the electricity consumption will most likely look a lot different in 2030 and 2035 compared to today (DEA 2022:53).

District heating

55 % of heating in the Danish system is by district heating. The district heating is a transmission system which can be connected to all types of heat production. Today district heating in Denmark is being produced on trash, wood shavings, straw, wind, solar heat, geothermic, natural gas, oil, coal, surplus heat from industry and more. 72% of the Danish district heating is produced on renewable energy like sun, wind, biomass, biogas and geothermic.

[143] https://ens.dk/en/our-responsibilities/wind-power/energy-islands/denmarks-energy-islands

District heating in Denmark is subject to a law that says that district heating companies cannot make profit. District heating in Denmark is non-profit[144].

The price on district heating varies a lot depending on type of fuel, type of facility etc. A big part of the price for district heating is constituted by the permanent tariff, and the consumption itself only constitutes a part of the price. This of course has the effect, that changes to the consumption have smaller effect on the heating bill.

The goal of the Danish Utility Regulator is to maintain a strong and effective supervision of the utility sectors – electricity, natural gas and district heating. [145]

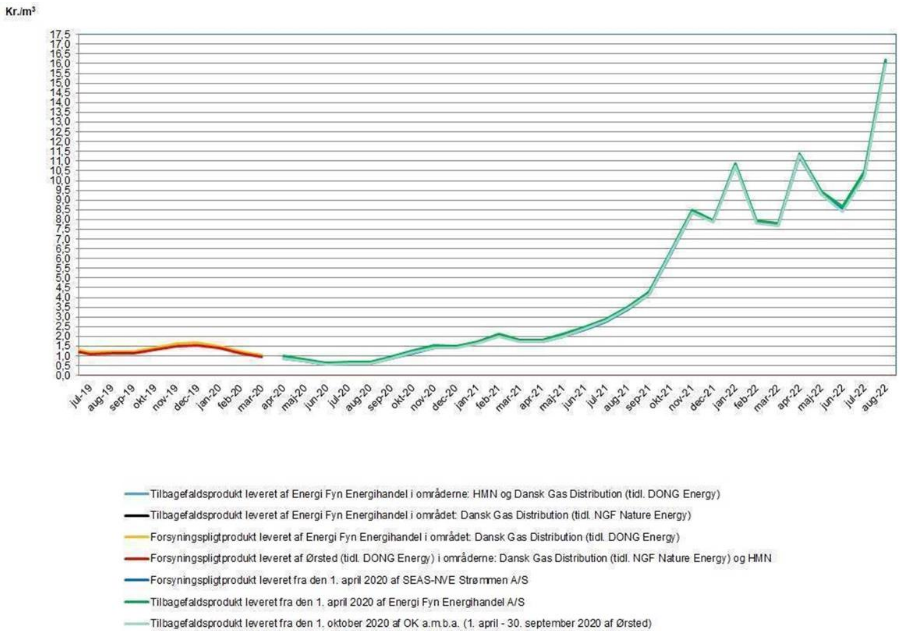


Figure 8-14: Gas price in Denmark. Source: https://forsyningstilsynet.dk/tal-fakta/priser/gaspriser

[144] Danish District Heating Association. https://www.danskfjernvarme.dk/presse/fakta-om-fjernvarme

[145] (https://forsyningstilsynet.dk/about-us)

9 Appendix K: Results from partners' questionnaires on technologies

9.1 Magnetocaloric heat pump

Organization: DANMARKS TEKNISKE UNIVERSITET (DTU) - Country: Denmark

TRL 5: Technology validated in relevant environment

Existing knowledge on markets: Have investigations been performed to map the possible market segments to which this solution can be applied?

- Yes

Business models: Have business models been designed according to which this solution can be brought to market? Market mapping / business case: If 'yes' or 'other', please add information on the progress. If possible, include links to public information.

- No

Market mapping / business case: If 'yes' or 'other', please add information on the progress. If possible, include links to public information.

- We have looked at the market for heat pumps, with the view to replace conventional vapour compression systems. Primarily, due to the low TRL we have done this from a performance and efficiency perspective. Other applications for the technology, especially within cooling have also been considered and market mapped. Again this has been mostly based on performance. Niche markets, where specialised requirements prevent conventional solutions have been considered by us and other groups/companies.

Competition: List the major competitors in the market deliver most the comparable technology / services.

- Conventional vapour compression heat pumps are the direct competitor in the sense that they have the same function of moving heat from a cold to a hot reservoir.

Highly compatible for:

- Residential (single family house)

Low compatible for:

- Offices (commercial or governmental, including mixed-use)
- Residential (multi-family apartments)
- Public buildings (e.g. civic buildings, educational or cultural buildings)

Are there requirements to the building skin energy performance in order to adopt this technology?

- Yes, the quality of building skin energy performance influences the performance of this technology.

List 3 attractive advantages of the solution

- The technology does not use refrigerant gasses, which in many cases can contribute to the greenhouse effect.
- Potentially the efficiency is higher than VC. This has been demonstrated to some extent in lab settings.

- The full process is liquid (water with some additives) based, so there is no heat exchange between liquid and gas.

List 3 challenges of the solution

- It is expensive, mostly due to the large magnet, which is required.
- The magnetocaloric effect of materials is mostly low.
- Devices become quite complex, due to the interplay between many components.

Technical barriers: While undergoing research and development of this solutions, which technical barriers did you come across which are still needed to overcome before implementation?

- The magnetocaloric effect of the known materials is too low for proper implementation. There is ongoing research on improving this. Also, the cost of permanent magnet (NdFeB based) is a barrier for the financial realization of the system.

Stimulating attitude: Consider the solution you are working on. Which stimulating attitudes of people will help push this solution?

- Desire to reduce the use of refrigerant gasses.
- Willingness to invest in new technology

Limiting attitude: Consider the solution you are working on. Which limiting attitudes of people will slow down the adaptation of this solution?

- Technology conservative.
- Putting low price over high performance

Climate change: The climate is changing. This results in different average temperatures, extreme weather, extreme drought or flooding and other unforeseen effects. Consider the risks of climate change, how will this affect the implementation or use of this solution?

- There are no direct correlations between climate change and the implementation. However, a warmer climate would mean a higher temperature of the cold reservoir, from where the heat is pumped. This would in turn increase the efficiency of the heat pump.

Economic constraints: Which barriers do you see which will limit the adoption of this technology? Make a list and order them qualitatively from high to low.

- Increase in cost of rare earth metals, which are currently mainly sourced from China, would increase the price of the technology

Economic opportunities: Which economic opportunities can you list, which support the fast adoption of this technology? Mix general trends and specific examples where you are aware of.

- Limitations in the use of refrigerant gasses could push the implementation of technologies not relying on these, such as the MCHP.

Energy market: How does the metering, payment or availability of grid capacity influence the adoption of this solution? Describe in general terms of stimuli and barriers.

- There is some degree of energy storage built into the technology, as the heat transfer is always through water. This would allow for some off-setting of the production vs. demand.

Which influences are relevant for implementation of this solution and have not been discussed before?

- Scientific discoveries of better magnetocaloric materials and/or cheaper or better permanent magnet materials. However, it is of course hard to predict such.

Customer segments: Which customer segments can be defined for this solution? These can be one or several customer segments which will be served. Think of building residents, building owners, MEP installation contractors, engineering firms, cooperations.

- Either heat pump installers, or heat pump consumers. This may be home owners, building owners etc.

Value proposition: Describe the value proposition for this solution. Which is problem will be solved for the entity (customer) which is being proposed and how will it satisfy him/her?

- Potentially higher efficiency, thus cheaper to run.

Channels: How would this proposition be delivered to the customer? Which channels of distribution are required to get this done?

- Sales channels (web shops; shops; sales portals); Communication channels (distribution of information)

Customer relationships: How will the relation with the customer be built and maintained during use? Will there be a service packages during the ownership phase / will there be a repair option / will there be regular updates?

- It would be expected that there would be some kind of service package, as with a conventional heat pump.

Key resources: Specific resources to deliver the value proposition. List the required resources in a qualitative way.

- Availability of the relevant materials at a reasonable cost.
- Relevant coupling to other technology, e.g. BTES.

Key activities: Which would the activities be that people need to perform in order to deliver the value proposition?

- Install and commission heat pump, and connect this to the rest of the domestic system.

Key partnerships: Which partnerships are required to get the value proposition to market? These could be partnerships to outsource activities or resources required from others. Other partnerships could be knowledge networks or business clubs.

- Knowledge networks on the technology would be required initially.

Cost structure: Last but not least, define in a qualitative way the cost structure of the proposition. List the cost elements which are most significant in the solution.

- Cost for materials, assembly and installation.

9.2 Multi-source heat pump

Organization:

- G. LIGEROS and SIA OE – PSYCTOTHERM (PSYCTO)
- NATIONAL CENTER FOR SCIENTIFIC RESEARCH "DEMOKRITOS" (NCSRD)

Country: Greece

TRL 7: System prototype demonstration in operational environment (PSYCTO)

TRL 5: Technology validated in relevant environment (NCSRD)

Existing knowledge on markets: Have investigations been performed to map the possible market segments to which this solution can be applied?

- Yes
- Only some first indications based on the operation/performance of the heat pump in the GR/DK pilots

Business models: Have business models been designed according to which this solution can be brought to market? Market mapping / business case: If 'yes' or 'other', please add information on the progress. If possible, include links to public information.

- No

Market mapping / business case: If 'yes' or 'other', please add information on the progress. If possible, include links to public information.

- The heat pump will probably fitting better for heating applications due to the very good performance, either in single-family houses or in larger buildings. For cooling its performance is similar to existing solutions (but with refrigerants with a higher GWP).

Competition: List the major competitors in the market deliver most the comparable technology / services.

- flexoTHERM by Vaillant (https://www.vaillant.co.uk/homeowners/products/the-flexotherm-multi-source-heat-pump-22464.html)
- Mitsubishi (https://les.mitsubishielectric.co.uk/products/commercial-heat pumps-and-chillers/commercial-heat-pumps/ecodan-crhv-monoblocground-water-source-heat-pump-system)
- Better Planet, UK (https://www.betterplanet.co.uk/multi-source-heat-pumps)
- China Palm, China (https://www.china-heat pump.com/category/heat-pumpproducts/multi-source-heat-pump/)

There are several heat pump manufacturers, but as far as I know none is providing a heat pump with:

1. multi-source (or dual-source) options, such as air- or water/brine-source

2. heat pump with a synthetic refrigerant with a GWP below 150. However, there are commercial heat pumps with natural refrigerants such as CO2 but not for heating and cooling (only heating)

Highly compatible for:

- Offices (commercial or governmental, including mixed-use)
- Residential (multi-family apartments)
- Public buildings (e.g. civic buildings, educational or cultural buildings)

For Residential (single family house), the participants have chosen both low and high compatibility.

Are there requirements to the building skin energy performance in order to adopt this technology?

- Yes, the quality of building skin energy performance influences the performance of this technology.

List 3 attractive advantages of the solution

- Efficient performance of the system, leading to reduced operation cost.
- Eco-friendliness of the system (combined with RES, eco-friendly refrigerant, no on-site emissions).
- Very limited maintenance.

- Low-GWP refrigernat (R454C, GWP=148)
- COP comparable to high-performing heat pumps for heating
- Flexibility due to the switch between heat sources (if applicable)

List 3 challenges of the solution

- A well dimensioned system can lead to significant operation cost savings, but the components estimation and selection needs to be precise.
- Select the right control/operation strategy, which leads to the appropriate heat source selection and leads to increased efficiency.
- Issues regarding the peak demand, as the heat pumps are connected to the electricity grid.

- Long-term operation and durability of the compressor with the selected refrigerant (scroll compressor not certified for R454C). Still up to now there are no compressors available for R454C with economizer/vapour-injection.
- Identify whether the multi-source option makes sense (in terms of additional costs and control complexity) and leads to an increased seasonal COP. In case of BTES availability, air-source operation is never applied according to the simulations.
- Optimize the operational parameters (e.g. refrigerant superheat at compressor or economizer suction, water flow rates) according to the mode (heating or cooling) and the heat source/sink temperatures. This requires further testing and fine-tuning at controllable conditions (not within the pilot tests, but after the project).

Technical barriers: While undergoing research and development of this solutions, which technical barriers did you come across which are still needed to overcome before implementation?

- Availability of a compressor with economizer for R454C to ensure the long lifetime of the heat pump. Related to this, within the last year some manufacturers started to produce compressor for R454C but not yet with economizer. This will be perhaps their next step.
- To make full use of the multi-source option, an efficient control is required to optimise the operation and performance. The PLC-based control of the heat pump relies on a rule-based control that has been developed according to best practice principles derived from the testing period. Therefore, some kind of BEMS control with optimisation features is needed to exploit its full potential.

Stimulating policies: Which policies or regulations in the EU-zone or specific countries are stimulating the application of this solution?

- Directive 2009/28/EC
- JRC, Renewables in the EU: the support framework towards a single energy market EU countries reporting under Article 22(1) b, e and f of Renewable Energy Directive, vol. 22, no. 1. 2017.
  (https://e3p.jrc.ec.europa.eu/sites/default/files/documents/publications/presentation_jrc110415_1.pdf)
- Energy Performance of Buildings Directives (https://epb.center/epbstandards/energy-performance-buildings-directive-epbd/)
- https://ec.europa.eu/commission/presscorner/detail/en/IP_22_3131
- https://www.consilium.europa.eu/en/policies/green-deal/fit-for-55-the-eu-plan-for-a-green-transition/

Stimulating attitude: Consider the solution you are working on. Which stimulating attitudes of people will help push this solution?

- Willing to reduce the global warming and on-site emissions.
- Willing to support the energy transition.
- Willing to incorporate cutting-edge technologies.
- wanting to pay less for heating, DHW and cooling
- willing to combine a device for heating and cooling (not having a separate boiler and AC units)

Limiting attitude: Consider the solution you are working on. Which limiting attitudes of people will slow down the adaptation of this solution?

- fear of changing a well-known technology, such as the gas-fired boilers
- fear that many technicians are unaware of more complex systems
- fear that need to reconstruct their buildings (eg change radiators or improve insulation, incorporate a PVT collector)
- heat pump cost is higher than individual boiler plus split AC units

- appliances need to be replaced (radiators to fan coils) with some cost

Climate change: The climate is changing. This results in different average temperatures, extreme weather, extreme drought or flooding and other unforeseen effects. Consider the risks of climate change, how will this affect the implementation or use of this solution?

- The increase of ambient temperature increases the performance of the air-source operation.
- The building insulation and size in combination with the climate conditions could increase the heating demand, leading to reduced system performance.
- cooling will start to be needed in more locations around Europe. So, reversible heat pumps for heating/cooling will probably increase their market share in the near future

Economic constraints: Which barriers do you see which will limit the adoption of this technology? Make a list and order them qualitatively from high to low.

- Increased cost of electricity because of the global situation of energy inconsistency. Need for high energy efficiency.
- Increasing cost of raw materials for the system manufacturing because of the global geopolitical situation.
- high cost of heat pump
- cost for fan coil appliances (for renovations only)

Economic opportunities: Which economic opportunities can you list, which support the fast adoption of this technology? Mix general trends and specific examples where you are aware of.

- https://www.gov.uk/domestic-renewable-heat-incentive
- https://www.greenmatch.co.uk/heat-pump/heat-pump-grant
- Increasing fossil fuel prices
- The Regulatory Assistance Project (RAP) has developed a report aiming to offer guidance on how to improve the EU’s Fit-for-55 package to encourage greater use of heat pumps (https://www.raponline.org/knowledge-center/the-perfect-fit-shaping-the-fit-for-55-package-todrive-a-climate-compatible-heat-pump-market/)
- Energy prices increase, both for electricity and gas, but their price ratio remains about the same. Even in such conditions, heat pumps are more cost-effective than gas boilers.

Energy market: How does the metering, payment or availability of grid capacity influence the adoption of this solution? Describe in general terms of stimuli and barriers.

- The possibility of malfunction at times of peak demand of electricity could be a problem for heat pump systems integration. Careful planning and infrastructure investment will be required to meet the additional demand for electricity.
- I think this is not relevant to the heat pump.

Which influences are relevant for implementation of this solution and have not been discussed before?

- There is need for 4th generation refrigerants or even natural refrigerants to be employed in order to reduce the impact on greenhouse effect and ozone depletion.
- Availability of good installers to perform the system commissioning. Especially for heat pumps, some lack of installers starts to appear.

Customer segments: Which customer segments can be defined for this solution? These can be one or several customer segments which will be served. Think of building residents, building owners, MEP installation contractors, engineering firms, cooperations.

- Building owners
- MEP installation contractors
- Engineering firms constructing buildings
- Mostly owners for small buildings. Engineering firms (or ESCO-like) for larger ones.

Value proposition: Describe the value proposition for this solution. Which is problem will be solved for the entity (customer) which is being proposed and how will it satisfy him/her?

- Reduced heating cost (for owners/residents)
- Very limited maintenance (for owners/residents)
- Eco-friendly profile (for owners/residents/engineering firms)
- Flexibility of operation according to the temperature of heat source to maximise the COP (if different heat sources are available).
- Low-GWP refrigerant

Channels: How would this proposition be delivered to the customer? Which channels of distribution are required to get this done?

- Communication channels (distribution of information)
- Logistic channels (distribution of goods)

Customer relationships: How will the relation with the customer be built and maintained during use? Will there be a service packages during the ownership phase / will there be a repair option / will there be regular updates?

- One of the key advantages of tis technology is the limited maintenance that these systems need. However, the customer will be advised for a regular maintenance with a suitable technician when it is needed, while it can also be offered as extra services.
- Not aware

Revenue streams: If this solution would be brought to market, it will result in a revenue stream. This will work when the value proposition is successfully offered to customers. Revenue streams can be monetary, but revenue can also come in the form of benefit to others than the customer: enhancing biodiversity, adding social value, data collection, ...

- Development of a new market for the company.
- Enhancement of the eco-friendly profile of the company.
- Development of a trustworthy profile for the company, with a significant social value.
- Enhancement of the high tech profile of the company.
- Not aware

Key resources: Specific resources to deliver the value proposition. List the required resources in a qualitative way.

- Availability of low GWP and ODP refrigerants for the muti-source heat pumps

- Availability of components based on the sizing that has been designed.
- availability of compressors for the selected low-GWP refrigerant (R454C).

Key activities: Which would the activities be that people need to perform in order to deliver the value proposition?

- Manufacturing
- Testing
- Installing and commissioning
- Further testing is needed.
- Up-scaling by considering other types of compressors (mostly screw) for larger applications, about >100 kWth.

Key partnerships: Which partnerships are required to get the value proposition to market? These could be partnerships to outsource activities or resources required from others. Other partnerships could be knowledge networks or business clubs.

- Check the correct operation of the equipment that will be combined with the heat pump (e.g. PVT, boreholes)
- Partnerships aiming to expand the information network.
- Not aware

Cost structure: Last but not least, define in a qualitative way the cost structure of the proposition. List the cost elements which are most significant in the solution.

- Raw materials (piping, compressor, heat exchangers, expansion devices)
- Electronic equipment for the control of the system (electric panel, PLC, instrumentation)
- Refrigerant and lubricating oil
- I guess costs for the components (mostly the compressor, the heat exchangers, the 3- and 4-way valves, the expansion valves), the electric panel (including the PLC, switches etc) and assembly. The cost of the refrigerant is very small compared to the components costs.

9.3 PV Thermal

Organization: HOGSKOLAN I GAVLE (HIG) – country: Portugal

- TRL 7: System prototype demonstration in operational environment

Organization: MG SUSTAINABLE ENGINEERING AB – country: Sweden

- TRL 8: System complete and qualified

Existing knowledge on markets: Have investigations been performed to map the possible market segments to which this solution can be applied?

- Yes (both partners)

Business models: Have business models been designed according to which this solution can be brought to market? Market mapping / business case: If 'yes' or 'other', please add information on the progress. If possible, include links to public information.

- No (by HIG)
- Yes (by MG SUSTAINABLE ENGINEERING AB)

Market mapping / business case: If 'yes' or 'other', please add information on the progress. If possible, include links to public information.

- By MG SUSTAINABLE ENGINEERING AB: We have reach a high TRL and we have investigate both which markets we should target and how we should target them. This is layout out in a new business plan.

Competition: List the major competitors in the market deliver most the comparable technology / services.

By HIG:

- Abora, EndeF, DualSun

by MG SUSTAINABLE ENGINEERING AB:

- Abora, TPV, DualSun, Endef, etc. All these brands have similar services but with some differentiation

Highly compatible for (by both partners):

- Offices (commercial or governmental, including mixed-use)
- Residential (single family house)
- Residential (multi-family apartments)
- Public buildings (e.g. civic buildings, educational or cultural buildings)

Are there requirements to the building skin energy performance in order to adopt this technology?

- No, system can be applied independent from building skin energy performance (by both partners)

List 3 attractive advantages of the solution

By HIG:

- Heat electrification.
- Monitoring and control over the production, while integrating several technologies.

by MG SUSTAINABLE ENGINEERING AB:

- With this solution, it is possible to obtain more energy per square meter of roof area, which increase the cost per square meter but reduces the cost per KWh (this being the most important number in solar)

List 3 challenges of the solution

By HIG:

- Low TRL.
- Short outdoor testing for the PVT system, to do a long exposure material test.

by MG SUSTAINABLE ENGINEERING AB:

- With this solution, it is possible to obtain more energy per square meter of roof area, which increase the cost per square meter but reduces the cost per KWh (this being the most important number in solar)

Technical barriers: While undergoing research and development of this solutions, which technical barriers did you come across which are still needed to overcome before implementation?

By HIG:

- Cheap, yet strong, materials to accommodate all the PVT receiver parts

by MG SUSTAINABLE ENGINEERING AB:

- Certification is a barrier. Current certification is design for either PV or T and not for PVT and much less for concentrating PVT.

Stimulating policies: Which policies or regulations in the EU-zone or specific countries are stimulating the application of this solution?

By HIG:

- Heat electrification policies.
- PV and ST incentives.

by MG SUSTAINABLE ENGINEERING AB:

- Several countries within EU have some level of support for either PV or for ST but PVT falls in the middle between PV and ST and often is not sufficiently recognized (because it is a little bit more complex to take into account the dual output). Overall incentives are limited today.

Limiting policies: Are there EU-wide policies or regulations or specific countries which are currently forming barriers for the solution to be implemented?

By HIG:

- EU lack an unified policie for PVT solar collectors.

by MG SUSTAINABLE ENGINEERING AB:

- Some good policies have been implemented such as the mandatory ST for new buildings in Portugal and later on in Spain as well. However, it also common, that excess electricity is given to grid for free (no system for compensation even at market level).

Stimulating attitude: Consider the solution you are working on. Which stimulating attitudes of people will help push this solution?

By HIG:

- Willing to go greener. Investing in greener solutions while reducing their energy bill.

by MG SUSTAINABLE ENGINEERING AB:

- The war in Ukraine will certainly do a lot in showing citizens the need to diversify.

Limiting attitude: Consider the solution you are working on. Which limiting attitudes of people will slow down the adaptation of this solution?

By HIG:

- Cost

by MG SUSTAINABLE ENGINEERING AB:

- fear of innovations
- conservatism

Climate change: The climate is changing. This results in different average temperatures, extreme weather, extreme drought or flooding and other unforeseen effects. Consider the risks of climate change, how will this affect the implementation or use of this solution?

By HIG:

- The modularity of PVT solar collectors cope with climate change.

by MG SUSTAINABLE ENGINEERING AB:

- PVT will couple well with many other technologies. HP is just one of them.

Economic constraints: Which barriers do you see which will limit the adoption of this technology? Make a list and order them qualitatively from high to low.

By HIG:

- Incentive for replacement of gas boiler by HP.

by MG SUSTAINABLE ENGINEERING AB:

- The governments should fund (on credit) RE solutions that require large upfront capital investments such as CSP, PV, Wind or ST. This can be done at domestic or business level (larger loans).

Economic opportunities: Which economic opportunities can you list, which support the fast adoption of this technology? Mix general trends and specific examples where you are aware of.

By HIG:

- Subsidies for PV and ST purchases, coupled with batteries, which will lead to a more grid independency.

by MG SUSTAINABLE ENGINEERING AB:

- I am not sure I understand this question.

Energy market: How does the metering, payment or availability of grid capacity influence the adoption of this solution? Describe in general terms of stimuli and barriers.

By HIG:

- Scarcity of materials.

by MG SUSTAINABLE ENGINEERING AB:

- The time of meeting is extremely relevant for any PV or PVT applications.

Which influences are relevant for implementation of this solution and have not been discussed before?

- None (by both partners)

Customer segments: Which customer segments can be defined for this solution? These can be one or several customer segments which will be served. Think of building residents, building owners, MEP installation contractors, engineering firms, cooperations.

by MG SUSTAINABLE ENGINEERING AB:

- PVT can be installed in any customer that has a low temperature heat demand (up to 80C) as well as an electrical demand.

Value proposition: Describe the value proposition for this solution. Which is problem will be solved for the entity (customer) which is being proposed and how will it satisfy him/her?

By HIG:

- High energy bills based on consumption of fossil fuels -> lower energy bills based on greener solutions.

by MG SUSTAINABLE ENGINEERING AB:

- Customers want to be green and reduce their energy bills. PVT can help with both.

Channels: How would this proposition be delivered to the customer? Which channels of distribution are required to get this done?

By HIG:

- Communication channels (distribution of information);Sales channels (webshops; shops; sales portals)

by MG SUSTAINABLE ENGINEERING AB:

- Logistic channels (distribution of goods);Communication channels (distribution of information);Sales channels (webshops; shops; sales portals);

Customer relationships: How will the relation with the customer be built and maintained during use? Will there be a service packages during the ownership phase / will there be a repair option / will there be regular updates?

By HIG:

- Technologies nowadays do not sell per se. they need to be coupled by an EMS in order for the customer to monitor/control all the production and consumption.

by MG SUSTAINABLE ENGINEERING AB:

- It is critical to create a relation of trust so that the customer advances with a new solution (PVT).
- PVT systems have relatively low maintenance when compared to other solution but again a good relation is important to ensure good messaging.

Revenue streams: If this solution would be brought to market, it will result in a revenue stream. This will work when the value proposition is successfully offered to customers. Revenue streams can be monetary, but revenue can also come in the form of benefit to others than the customer: enhancing biodiversity, adding social value, data collection, ...

by MG SUSTAINABLE ENGINEERING AB:

- PVT needs to prove itself in the market in order to ensure that it gets included in the wider offer of subsidies and certification for example.

Key resources: Specific resources to deliver the value proposition. List the required resources in a qualitative way.

by MG SUSTAINABLE ENGINEERING AB:

- It is critical to have extremely capable:
  - Installers
  - System designers
  - Sales personnel
  - Production Team

Key activities: Which would the activities be that people need to perform in order to deliver the value proposition?

Key partnerships: Which partnerships are required to get the value proposition to market? These could be partnerships to outsource activities or resources required from others. Other partnerships could be knowledge networks or business clubs.

By HIG:

- Partnerships with energy producers or retailers

by MG SUSTAINABLE ENGINEERING AB:

- We would need to partner with strong sales and installers world wide to ensure rapid dissemination of the solution.

Cost structure: Last but not least, define in a qualitative way the cost structure of the proposition. List the cost elements which are most significant in the solution.

By HIG:

- Quality of installers is a most.

by MG SUSTAINABLE ENGINEERING AB:

- The PVT collector is the heart of the system but it doesn´t work at all without the remaining parts. The collector itself will account for about 30% of the total cost of the installed system (being labour and other system equipment the remaining 70%)

9.4 Building Energy Management System

Organization: THERMOVAULT BVBA (THERMOVAULT), Country: Netherlands

- TRL 5: Technology validated in relevant environment (by THERMOVAULT - Netherlands)

Organization: NATIONAL CENTER FOR SCIENTIFIC RESEARCH “DEMOKRITOS” (NCSRD) Country: Greece

- NCSRD is not involved in the BEMS, but rather in the system simulation. I provide answers related to this.
- TRL 5: Technology validated in relevant environment (by NCSRD - Greece)

Existing knowledge on markets: Have investigations been performed to map the possible market segments to which this solution can be applied?

- No (both partners)

Business models: Have business models been designed according to which this solution can be brought to market? Market mapping / business case: If 'yes' or 'other', please add information on the progress. If possible, include links to public information.

- No (both partners)

Competition: List the major competitors in the market deliver most the comparable technology / services.

by THERMOVAULT - Netherlands

- Smart thermostats/smart home (Google/Nest, Honeywell, Quby), HVAC/building energy management (Daikin, Mitsubishi, Siemens)

by NCSRD – Greece:

- Not in the market, but among other research organizations that provide such solutions/services to third parties. Other "competitors" could be universities or research centers

Highly compatible for (by both partners):

- Offices (commercial or governmental, including mixed-use)
- Residential (single family house)
- Residential (multi-family apartments)
- Public buildings (e.g. civic buildings, educational or cultural buildings)

Are there requirements to the building skin energy performance in order to adopt this technology?

- No, system can be applied independent from building skin energy performance (by both partners)

List 3 attractive advantages of the solution by THERMOVAULT – Netherlands:

- Portable to different building types
- Low cost in comparison to commercial offerings for larger buildings
- Offers advanced control also for smaller buildings

by NCSRD – Greece:

- Component database to include or exclude several components
- Some component models have been validated based on the available tests (e.g. PVT, heat pump)
- Source code developed by NCSRD and is available for future changes/improvements

List 3 challenges of the solution

by THERMOVAULT – Netherlands:

- Device compatibility
- Not bundled with energy system
- Not sufficiently developed for commercial use (TRL5)

by NCSRD – Greece:

- Not user-friendly (use case is changed by modifying in txt files some parameters)
- External software is needed to prepare in tables the weather data (from Trnsys) and building demand (from an in-house Python code or any other source)
- Integrate some smart-control features instead of rule-based control that is currently implemented

Technical barriers: While undergoing research and development of this solutions, which technical barriers did you come across which are still needed to overcome before implementation?

by THERMOVAULT – Netherlands:

- Hardware and software reliability, reliability of the energy systems themselves, cloud operating costs, device interoperability, specification/configuration of energy systems, enterprise network configuration, network connectivity, component sourcing.

by NCSRD – Greece:

- None to implement the software for the RES4BUILD needs. For other projects/cases, modifications to the source code might be needed accoridng to the energy system configuration.

Which policies or regulations in the EU-zone or specific countries are stimulating the application of this solution?

by THERMOVAULT – Netherlands:

- Efforts to standardize the description and control of energy systems, e.g. EEBUS and FAN EFI. Subsidies for smart/controllable devices. Policies leading to high energy costs.

by NCSRD – Greece:

- None relevant to the simulation software.

Limiting policies: Are there EU-wide policies or regulations or specific countries which are currently forming barriers for the solution to be implemented?

- None (by both partners)

Stimulating attitude: Consider the solution you are working on. Which stimulating attitudes of people will help push this solution?

by THERMOVAULT – Netherlands:

- Consideration of the control and compatibility before purchase of the components. Willingness to save energy. Interest in advanced energy systems. Tolerance for problems with immature technology.

by NCSRD – Greece:

- None relevant to the simulation software.

Limiting attitude: Consider the solution you are working on. Which limiting attitudes of people will slow down the adaptation of this solution?

by THERMOVAULT – Netherlands:

- Short ROI windows. Unwillingness to change systems. Lack of cooperation between vendors.

by NCSRD – Greece:

- None relevant to the simulation software.

Climate change: The climate is changing. This results in different average temperatures, extreme weather, extreme drought or flooding and other unforeseen effects. Consider the risks of climate change, how will this affect the implementation or use of this solution?

by THERMOVAULT – Netherlands:

- Cooling demand will increase. Cooling COP will decrease. BTES performance may decrease as more devices are connected. PV output decreases with increased temperature. PVT output increases. Electronics become less reliable at higher temperatures. Extreme weather events may damage the PV and PVT systems.

by NCSRD – Greece:

- None relevant to the simulation software.

Economic constraints: Which barriers do you see which will limit the adoption of this technology? Make a list and order them qualitatively from high to low.

by THERMOVAULT – Netherlands:

- Cheap energy from the grid. Installation cost. Availability of installers. Relevant competence of installers. Component shortages, especially for heat pumps. Electronics cost. Conflicting/competing control from other energy devices (batteries, EVs).

by NCSRD – Greece:

- None relevant to the simulation software.

Economic opportunities: Which economic opportunities can you list, which support the fast adoption of this technology? Mix general trends and specific examples where you are aware of.

by THERMOVAULT – Netherlands:

- Subsidies on/funding schemes for energy systems coupled to having a control system for it, rewards for keeping the system running efficiently over time, (re)training of installers, legislation which requires (standardized) controllability, local manufacturing of key components.

by NCSRD – Greece:

- None relevant to the simulation software.

Energy market: How does the metering, payment or availability of grid capacity influence the adoption of this solution? Describe in general terms of stimuli and barriers.

by THERMOVAULT – Netherlands:

- Inside the household it is difficult to obtain information on tariff information, at this moment it needs to be tailored for each installation. Access to (smart) meter data is different per country, and may be subject to administrative processes. In-household communication between devices is challenging. The tariff structure influences the optimization problem. Communication volumes and switch frequencies may change depending on what control needs to be offered, depending on the tariff structure at hand. More granular controllable devices may be desired depending on the precise terms and conditions of the tariff structure (e.g. control over the modulation of a heat pump).

Which influences are relevant for implementation of this solution and have not been discussed before?

by THERMOVAULT – Netherlands:

- Possible market entry by tech (Tesla, Google, Apple) and energy giants (Total, Shell).

by NCSRD – Greece:

- None relevant to the simulation software.

Customer segments: Which customer segments can be defined for this solution? These can be one or several customer segments which will be served. Think of building residents, building owners, MEP installation contractors, engineering firms, cooperations.

by THERMOVAULT – Netherlands:

- Early adopters, building owners, installation contractors, cooperations, energy companies (resale), device vendors (bundled).

by NCSRD – Greece:

- Engineering firms (probably small ones) that have no access to commercial software and are willing to provide custom-made solutions to their clients.

Value proposition: Describe the value proposition for this solution. Which is problem will be solved for the entity (customer) which is being proposed and how will it satisfy him/her?

by THERMOVAULT – Netherlands:

- The solution provides better control of the energy system and thereby gives lower energy costs. In current economic conditions may building owners are pressured to lower energy costs.

by NCSRD – Greece:

- Identify the most suitable sizing of system components (e.g. heat pump capacity, tanks volume) to ensure that the (estimated) heating/cooling demand is covered. This can lead to cost reduction by not oversizing some components.

Channels: How would this proposition be delivered to the customer? Which channels of distribution are required to get this done?

by THERMOVAULT – Netherlands:

- Sales channels (webshops; shops; sales portals);Communication channels (distribution of information);Logistic channels (distribution of goods)

by NCSRD – Greece:

- Communication channels (distribution of information);

Customer relationships: How will the relation with the customer be built and maintained during use? Will there be a service packages during the ownership phase / will there be a repair option / will there be regular updates?

by THERMOVAULT – Netherlands:

- There will be support needed to incorporate new and replaced components. More interaction with other vendors may be demanded. There need to be updates to account for changes in tariff structure. Other heating technologies may become available or become popular (e.g. auxiliary heating with hydrogen or biofuels).

by NCSRD – Greece:

- Such next steps are not yet examined nor any plan is defined.

Revenue streams: If this solution would be brought to market, it will result in a revenue stream. This will work when the value proposition is successfully offered to customers. Revenue streams can be monetary, but revenue can also come in the form of benefit to others than the customer: enhancing biodiversity, adding social value, data collection, ...

by THERMOVAULT – Netherlands:

- Energy savings lead to decreased energy bills. End users may have increased comfort.

by NCSRD – Greece:

- This will be a service to third parties, once it is ready for the next steps.

Key resources: Specific resources to deliver the value proposition. List the required resources in a qualitative way.

by THERMOVAULT – Netherlands:

- predictable user behaviour
- suitable instrumentation in buildings
- standardized controllable devices

by NCSRD – Greece:

- Estimation of the heating/cooling demand of the bulding. If nothing is available, we can produce some estimations based on typical parameters (e.g. U values of the building), but there will be a high uncertainty.

Key activities: Which would the activities be that people need to perform in order to deliver the value proposition?

by THERMOVAULT – Netherlands:

- install and configure the system
- educate users on the proper use of the system
- maintain the system on changes to energy system or cost structure

by NCSRD – Greece:

- Provision of necessary input data for the building(s) of concern

Key partnerships: Which partnerships are required to get the value proposition to market? These could be partnerships to outsource activities or resources required from others. Other partnerships could be knowledge networks or business clubs.

by THERMOVAULT – Netherlands:

- vendors of energy components
- energy system integrators
- installers

by NCSRD – Greece:

- Probably there will be the need to create a spin-off company of NCSRD to exploit this solution/software.

Cost structure: Last but not least, define in a qualitative way the cost structure of the proposition. List the cost elements which are most significant in the solution.

by THERMOVAULT – Netherlands:

- For the BEMS, the cost is in up-front hardware and software development cost. At start there is installation cost. During operation there is cloud/communication cost, and cost to keep the system compatible with upcoming standards.

by NCSRD – Greece:

- Costs for personnel to further improve the software and apply it.

9.5 Borehole Thermal Energy System – Controller

Organization: VLAAMSE INSTELLING VOOR TECHNOLOGISCH ONDERZOEK N.V. (VITO)

Country: Belgium

TRL 3: Experimental proof of concept

Existing knowledge on markets: Have investigations been performed to map the possible market segments to which this solution can be applied?

- Yes

Business models: Have business models been designed according to which this solution can be brought to market? Market mapping / business case: If 'yes' or 'other', please add information on the progress. If possible, include links to public information.

- Yes
- VITO has outsourced a market study on the BTES controller to Enerdata, this study is confidential but is used to fill in the questions in this questionnaire. If additional information is desired, please contact me and I'll check if we can share it.
    - Suggested business models:
        - Integrate BTES controller in an ESCO's or project owner's offer
        - Make a partnership with a BMS supplier to offer a specific BMS solution for a BMS

Competition: List the major competitors in the market deliver most the comparable technology / services.

- Accenta [ESCO]: France, Germany, India and China offer energy as a service and also controls biomass boilers and air/air heat pumps
- Energy Machines [ESCO]: Sweden, sells services for energy systems in buildings and also controls PV, battery, air/air heat pumps and wind turbines
- Celsius [ESCO]: France
- Adven [ESCO]: Norway, Sweden, Finland, Estonia and Latvia, offers energy as a service and also controls air/air heat pumps and PV
- Other potential competitors: Aspian Viak (Norway), Helen (Finland), Goblet Lavandier (Luxembourg), Geo en (Germany)
- Other indirect competitors: air/air HP installers, biomass boiler installer, ATES and HT-BTES installer

Highly compatible for:

- Offices (commercial or governmental, including mixed-use)
- Residential (multi-family apartments)
- Public buildings (e.g. civic buildings, educational or cultural buildings)

Low compatibility:

- Residential (single family house)

Are there requirements to the building skin energy performance in order to adopt this technology?

- No, system can be applied independent from building skin energy performance

List 3 attractive advantages of the solution

- Besides optimal control for a BTES it can also be used to size a BTES installation
- Carbon emission reduction
- Long Term performance and security of heat/cold supply

List 3 challenges of the solution

- Small Serviceable Available Market (SAM): solution is only relevant in large projects where backup units can take over the whole demand of the BTES, currently most BTES installations are built without backup installations
- Lack of maturity in the field to prove the added value of the controller
- Separation of players (BMS integration, BMS manufacturing, BTES Design) makes adoption of the solution more complex

Technical barriers: While undergoing research and development of this solutions, which technical barriers did you come across which are still needed to overcome before implementation?

- Getting access to the right measurements of the existing installation

Limiting policies: Are there EU-wide policies or regulations or specific countries which are currently forming barriers for the solution to be implemented?

- No

Stimulating attitude: Consider the solution you are working on. Which stimulating attitudes of people will help push this solution?

- Willingness to integrate advanced control functions in existing systems
- Willingness to share the necessary measurements

Limiting attitude: Consider the solution you are working on. Which limiting attitudes of people will slow down the adaptation of this solution?

- Conservatism

Climate change: The climate is changing. This results in different average temperatures, extreme weather, extreme drought or flooding and other unforeseen effects. Consider the risks of climate change, how will this affect the implementation or use of this solution?

- Warm summers and cold winters will increase the potential as it enables a higher heat input to the BTES in summer which results in a higher heat output in winter.

Economic constraints: Which barriers do you see which will limit the adoption of this technology? Make a list and order them qualitatively from high to low.

- Expensive backup installations lead to over-dimensioned BTES integrations without backup equipment. These installations have no need for our controller.

Economic opportunities: Which economic opportunities can you list, which support the fast adoption of this technology? Mix general trends and specific examples where you are aware of.

- Higher energy prices will improve the business case for the BTES controller as it can be used to limit the offtake of electricity from the grid or it can even shift the offtake of the grid in case of real-time prices.

Customer segments: Which customer segments can be defined for this solution? These can be one or several customer segments which will be served. Think of building residents, building owners, MEP installation contractors, engineering firms, cooperations.

- BTES Designer (engineering office)
- Operator/ESCO

Value proposition: Describe the value proposition for this solution. Which is problem will be solved for the entity (customer) which is being proposed and how will it satisfy him/her?

- Enables the BTES designer to design a BTES and backup installation of optimal size
- Enables the operator/ESCO to controlt the BTES in an optimal way maximising the storage function of the BTES and minimizing carbon emissions.

Channels: How would this proposition be delivered to the customer? Which channels of distribution are required to get this done?

- Communication channels (distribution of information)

Customer relationships: How will the relation with the customer be built and maintained during use? Will there be a service packages during the ownership phase / will there be a repair option / will there be regular updates?

- Service packages and regular updates are mandatory for this solution

Key resources: Specific resources to deliver the value proposition. List the required resources in a qualitative way.

- Availability of monitoring/measurement equipment (if not present --> install)
- Skilled people to install the complete workflow from reading in the measurements, calculating the optimal control to applying the control signal on the system

Key activities: Which would the activities be that people need to perform in order to deliver the value proposition?

- Installing extra measurement equipment (if not available)
- Deploying the solution so it can read out measurements from the installation and send control signals to the installation

Key partnerships: Which partnerships are required to get the value proposition to market? These could be partnerships to outsource activities or resources required from others. Other partnerships could be knowledge networks or business clubs.

- The BTES Booster has to be integrated into a complete offer. Pure players (e.g., BMS integration, BMS manufacturing,
- engineering office) will only be integration partners but not customers.

Cost structure: Last but not least, define in a qualitative way the cost structure of the proposition. List the cost elements which are most significant in the solution.

- Costs for developing the BTES controller software
- Costs for deploying the BTES controller software in the field
- Limited costs for adding extra measurement equipment if necessary

9.6 Simulation platform (grey/white box modelling)

Organization: VLAAMSE INSTELLING VOOR TECHNOLOGISCH ONDERZOEK N.V. (VITO)

Country: Belgium

TRL 4: Technology validated in lab

Existing knowledge on markets: Have investigations been performed to map the possible market segments to which this solution can be applied?

- No

Business models: Have business models been designed according to which this solution can be brought to market?

- No

Highly compatible for:

- Offices (commercial or governmental, including mixed-use)
- Residential (single family house)
- Residential (multi-family apartments)
- Public buildings (e.g. civic buildings, educational or cultural buildings)

Are there requirements to the building skin energy performance in order to adopt this technology?

- No, system can be applied independent from building skin energy performance

List 3 attractive advantages of the solution

- Generic configuration of different simulation scenarios
- Easy to extend with new models of buildings or equipment
- Usable for simulation and optimization

List 3 challenges of the solution

- Multizone models are complex to model
- Convergence problems which lead to unsolvable scenarios
- No graphical user interface available to configure the simulation scenarios

Technical barriers: While undergoing research and development of this solutions, which technical barriers did you come across which are still needed to overcome before implementation?

- Multizone models in which different rooms have different heat inputs are complex to implement and have not yet been taken into account.

Stimulating policies: Which policies or regulations in the EU-zone or specific countries are stimulating the application of this solution?

- The simulation framework itself + models are used mainly to simulate different scenarios etc and thus questions like these do not really apply to this solution. However, we will also fill out the questions in the energy management system part, which contains the smart controller and thus also (part of) the simulation framework, in which we will answer these questions

Limiting policies: Are there EU-wide policies or regulations or specific countries which are currently forming barriers for the solution to be implemented?

- See answer for stimulating policies

Stimulating attitude: Consider the solution you are working on. Which stimulating attitudes of people will help push this solution?

- See answer for stimulating policies

Limiting attitude: Consider the solution you are working on. Which limiting attitudes of people will slow down the adaptation of this solution?

- See answer for stimulating policies

Climate change: The climate is changing. This results in different average temperatures, extreme weather, extreme drought or flooding and other unforeseen effects. Consider the risks of climate change, how will this affect the implementation or use of this solution?

- Not applicable

Economic constraints: Which barriers do you see which will limit the adoption of this technology? Make a list and order them qualitatively from high to low.

- See answer for stimulating policies

Energy market: How does the metering, payment or availability of grid capacity influence the adoption of this solution? Describe in general terms of stimuli and barriers.

- See answer for stimulating policies

Customer segments: Which customer segments can be defined for this solution? These can be one or several customer segments which will be served. Think of building residents, building owners, MEP installation contractors, engineering firms, cooperations.

- Grey-box models : Scientists and research and technology organisations, Electricity market players/DSOs, Energy Servcice Companies (ESCO), District Heating System owners
- Optimization framework: Scientists and research and technology organisations, Energy service companies (ESCOs), building owners

Value proposition: Describe the value proposition for this solution. Which is problem will be solved for the entity (customer) which is being proposed and how will it satisfy him/her?

Grey box models:

- Scientist and research and technology organisations: the models can improve the efficiency of working on applications using the thermal flexibility of buildings. The models are readily available, and scientists can use them out of the box by feeding in measurements or sample data from the building to train the model. Once the model is trained, they can be easily integrated into any application.
- Electricity market players (aggregators)/DSOs can use the models to aggregate the total thermal flexibility in their portfolio and transform it into electrical flexibility that they can then use to bid on the electricity market or to balance their portfolio.
- District Heating System owners can use the models to aggregate the total thermal flexibility of the buildings connected to their network. Based on this they can use it for applying

different objectives on the network, e.g. reduction of heat losses, optimization of the central production plant, peak shaving etc, while maintaining the end user's comfort by keeping the indoor temperature between a predefined lower and upper boundary.

- Optimization framework:
- Scientists and research and technology organisations will be able to use the framework to carry out optimizations and simulations or use it for real-time control in labs or pilots.
- ESCOs/Energy suppliers can use the framework for carrying out optimal building control in the buildings of their clients, minimizing the energy cost and maximising the self-consumption.
- Building owners can use the framework to integrate the optimal control into the BEMS of their building

Channels: How would this proposition be delivered to the customer? Which channels of distribution are required to get this done?

- Communication channels (distribution of information); Sales channels (web shops; shops; sales portals);Tech transfer

Customer relationships: How will the relation with the customer be built and maintained during use? Will there be a service packages during the ownership phase / will there be a repair option / will there be regular updates?

- There should be an option to provide regular updates to enable new features or fix bugs

Key resources: Specific resources to deliver the value proposition. List the required resources in a qualitative way.

- Skills and capacity of people to understand the building modelling and optimization framework in order to extend the solution with new features and to do the tech transfer to interested customers if desired.

Key activities: Which would the activities be that people need to perform in order to deliver the value proposition?

- Guiding the deployment process of the software at the customer and testing if the solution works.

Key partnerships: Which partnerships are required to get the value proposition to market? These could be partnerships to outsource activities or resources required from others. Other partnerships could be knowledge networks or business clubs.

- For a research institute (e.g. VITO) a parntership with a system integrator is needed as we as a research institute will not provide 24/7 support

Cost structure: Last but not least, define in a qualitative way the cost structure of the proposition. List the cost elements which are most significant in the solution.

- Development (highest cost)
- Training of the people that have to work with the solution

- Recurring costs of support and updates with new features

9.7 The concept of Co-design and IES

Organization: BALTYCKA AGENCJA POSZANOWANIA ENERGII SP ZOO (BAPE) - Country: Poland

Technology readiness: Not applicable; no technology

Existing knowledge on markets: Have investigations been performed to map the possible market segments to which this solution can be applied?

- There is practically no experience in implementing a co-design service. Typically, there are energy consulting companies, design companies, technology and materials providers and contractors present on the market but they usually work independently and do not cooperate with each other. Sometimes investments are carried out on a "turnkey" basis. However, this means compiling design and execution services. This system lacks elements such as energy consulting, and above all, cooperation with stakeholders - mainly end recipients of the service.

Business models: Have business models been designed according to which this solution can be brought to market?

- No. Currently, there is no business model for the co-design service on the market due to lack of experience in this field.

Market mapping / business case: If 'yes' or 'other', please add information on the progress. If possible, include links to public information.

- As there is no room for comments in questions 10 and 11, we use the space in this question:
  Question 10: The co-design service can be used in all types of buildings - without restrictions. The involvement of end users in the co-design process may have a positive effect on the choice of the scope of investment, the course of implementation process and, finally, the end result.
  Question 11: Energy performance of a building affects the scope of the project, which in turn affects the total cost of the investment and the possibilities of its financing.

Competition: List the major competitors in the market deliver most the comparable technology / services.

- EPC (Energy Performance Contracting) may be a major competitor on the market. However, these types of services are also not popular in Poland. Barriers to the development of such services include limited trust in entrusting investments "in one hand" as well as long return periods of thermal modernization investments such as walls insulation or windows replacement. The shortest payback period is characteristic for modernization of internal installations (excluding its replacement) or exchange of heat sources. However, these actions are reasonable in case of already insulated buildings. In cases where it is necessary to insulate a building the payback period is significantly extended. As a result, EPC companies are not interested in such investments. They are mostly willing to engage in replacement of street lighting instead

Highly compatible for:

- Offices (commercial or governmental, including mixed-use)
- Residential (single family house)
- Residential (multi-family apartments)
- Public buildings (e.g. civic buildings, educational or cultural buildings)

Are there requirements to the building skin energy performance in order to adopt this technology?

- Yes, the quality of building skin energy performance influence the performance of this technology.

List 3 attractive advantages of the solution

- The co-design service is a comprehensive solution. Investors take part in the decision-making process from the beginning of the investment and have influence on the scope of the project. Co-design covers meetings, awareness-raising campaigns and stakeholder consultations. It is a win-win for both sides of the decision-making process. Case studies carried out as part of the RES4BUILD project have shown that co-design is particularly important in changing legal environment and energy market. It is very difficult for end users to make investment decisions, especially in unstable legal and market conditions. Co-design creates opportunities for a joint discussion on alternative solutions and consequences resulting from their implementation as well as making optimal decisions.

List 3 challenges of the solution

- The service is currently neither universal nor standardized in any way. There is lack of extensive information in this regard, examples of good practices or guidelines. The co-design process is a more time-consuming solution, as it requires tight cooperation with different types of stakeholders and building mutual trust.

Technical barriers: While undergoing research and development of this solutions, which technical barriers did you come across which are still needed to overcome before implementation?

- Not an issue.

Stimulating policies: Which policies or regulations in the EU-zone or specific countries are stimulating the application of this solution?

- Regional Strategic Programme on Environment and Energy Safety for Pomerania Region (2030) followed by European Funds for Pomerania 2021-2027 programme (draft under negotiations with EU) will support investments in integrated energy systems, including so-called ‘energy islands’. The co-design service would be particularly recommended for such solutions, due to wide range of technologies included and organizational complexity of such projects. There is no direct reference to co-design services in the documents, however, activities planned in the field of information and advisory services for SMEs include creation of a regional network of information desks providing comprehensive information for SMEs in one-stop-shop formula. Such one-stop-shop could offer a co-design service.

Limiting policies: Are there EU-wide policies or regulations or specific countries which are currently forming barriers for the solution to be implemented?

- In Poland, the national recovery plan is still not being implemented (August 2022) The plan supports i.a. creation of energy cooperatives and energy clusters where the co-design service could play an important role as project stimulator. The delays will hinder country's energy transition as well as expand the area of energy poverty.

Stimulating attitude: Consider the solution you are working on. Which stimulating attitudes of people will help push this solution?

- The basis is to build trust between stakeholders as well as willingness to cooperate in the long term. It takes time to properly prepare a project and achieve consensus among stakeholders. Readiness to implement novel service solutions is also important.
- At the same time, the co-design service should cover the entire process of joint development/preparation and implementation with stakeholders. It is a convenient solution for the investor.

Limiting attitude: Consider the solution you are working on. Which limiting attitudes of people will slow down the adaptation of this solution?

- Fear of implementing new solutions is natural. There may be a concern that solutions offered will be particularly beneficial for the device/technology provider and not for the end-user.
- Expectations of the parties may also differ. End-user expects the service to provide the best solution at a reasonable cost. The co-design requires more time to discuss optimal solutions, both in terms of technologies planned as well as organizational and financing aspects of the project. It requires educational and promotional activities. This is associated with additional costs and longer implementation period.

Climate change: The climate is changing. This results in different average temperatures, extreme weather, extreme drought or flooding and other unforeseen effects. Consider the risks of climate change, how will this affect the implementation or use of this solution?

- The co-design service has no direct impact on the climate. However, it can contribute to more informed decision-making, also in terms of its impact on the climate, thanks to the use of renewable energy sources.

Economic constraints: Which barriers do you see which will limit the adoption of this technology? Make a list and order them qualitatively from high to low.

- The co-design service may involve additional costs of meetings, training and promotional materials, etc.

Economic opportunities: Which economic opportunities can you list, which support the fast adoption of this technology? Mix general trends and specific examples where you are aware of.

- On the other hand, the offer of the service package should be cheaper than individual services/technologies ordered by the investor.

Energy market: How does the metering, payment or availability of grid capacity influence the adoption of this solution? Describe in general terms of stimuli and barriers.

- Unstable energy market, uncertainty as to national priorities, changing rules regarding prosumers, price instability of energy carriers, rising labor prices - all these factors make it difficult to assess what direction the energy transition will take. Therefore, co-design is currently very difficult to uptake as it involves making reasonable investment decisions. It may turn out that today's investment decisions, even if supported by currently more favorable financing conditions, may prove to be expensive to operate for many years (electricity price, gas price).

Other: Which influences are relevant for implementation of this solution and have not been discussed before?

- During the RES4BUILD project, war broke out in Ukraine. As a consequence, energy markets have been destabilized and the consequences are now difficult to predict.

Customer segments: Which customer segments can be defined for this solution? These can be one or several customer segments which will be served. Think of building residents, building owners, MEP installation contractors, engineering firms, cooperations.

- All stakeholders mentioned above are involved in the co-design service.

Value proposition: Describe the value proposition for this solution. Which is problem will be solved for the entity (customer) which is being proposed and how will it satisfy him/her?

- The co-design service allows for the involvement of only one company/entity dealing with different technologies, engineering solutions, providing energy, design and financial consulting. It simplifies the whole investment process for the customer and in the future may help to create a kind of ranking of co-design service providers. This will bring more trust/safety to the market causing higher interest in such solutions leading to faster and incleased development of such projects.

Channels: How would this proposition be delivered to the customer? Which channels of distribution are required to get this done?

- Communication channels (distribution of information); Sales channels (webshops; shops; sales portals);trainings, workshops, conferences, one-stop-shops

Customer relationships: How will the relation with the customer be built and maintained during use? Will there be a service packages during the ownership phase / will there be a repair option / will there be regular updates?

- Common meetings, workshops and decision-making process are quite specific for co-design service. This helps in building mutual trust and facilitates decision making.

Revenue streams: If this solution would be brought to market, it will result in a revenue stream. This will work when the value proposition is successfully offered to customers. Revenue streams can be monetary, but revenue can also come in the form of benefit to others than the customer: enhancing biodiversity, adding social value, data collection, ...

- The co-design service contributes to raising awareness on climate problems. Solutions proposed should lead to energy costs reduction and implementation of innovative technologies.

Key resources: Specific resources to deliver the value proposition. List the required resources in a qualitative way.

- Skills and capacity of people to offer a comprehensive co-design service are crucial for the successful implementation of the idea.

Key activities: Which would the activities be that people need to perform in order to deliver the value proposition?

- Organization and creation of energy co-operative starting from the stakeholders, energy, companies, legal issues, agreements, decision making process, etc.
- Guiding the implementation of the project
- Testing, commissioning, maintenance

Key partnerships: Which partnerships are required to get the value proposition to market? These could be partnerships to outsource activities or resources required from others. Other partnerships could be knowledge networks or business clubs.

- Co-design service may require partnerships of suppliers of individual technologies (PV, heat pumps, heating installations, insulation), as well as technical consultants, designers and installers.

Cost structure: Last but not least, define in a qualitative way the cost structure of the proposition. List the cost elements which are most significant in the solution.

- In addition to typical investment costs, there may also be costs of workshops, promotional campaigns, organization of meetings with stakeholders, cooperation with suppliers of individual technologies.

9.8 Application of LCA / LCE analysis methods in practice

Organization: UNIVERSITAET STUTTGART (USTUTT) - Country: Germany

TRL 9: Actual system proven in operational environment

Existing knowledge on markets: Have investigations been performed to map the possible market segments to which this solution can be applied?

- Yes

Business models: Have business models been designed according to which this solution can be brought to market?

- Yes

Competition: List the major competitors in the market deliver most the comparable technology / services.

- Because our focus is on most cases research and analyses combined with life cycle assessment, we are competing mainly with other research institutions. Free market service providers can conduct conventional product LCAs or EPDs much more efficient, than we, so we are mainly not competing with those on their "day to day" business, I would say.

Highly compatible for:

- Offices (commercial or governmental, including mixed-use)
- Residential (single family house)
- Residential (multi-family apartments)
- Public buildings (e.g. civic buildings, educational or cultural buildings)

Are there requirements to the building skin energy performance in order to adopt this technology?

- No, system can be applied independent from building skin energy performance

List 3 attractive advantages of the solution

- Life cycle assessment provides a holistic view on a product, system or service. The method provides a very good, standardized framework to investigate and expose originators of environmental impacts under given boundaries. In general the method is highly flexible in terms of goal and scope, data used (generic/specific), system boundaries and evaluation options (e.g. different Impact category and indicators).

List 3 challenges of the solution

- LCA modelling can be complex, and expertise of the assessed product is necessary. The principle "garbage in, garbage out" applies: You can generate results with very little knowledge and many assumptions, but those are not of high quality. Because you often only see the aggregated results condensed to one number, it is often difficult to judge those numbers without knowing the model and background. LCA results are often difficult to communicate because they are just numbers. If you are not an expert in LCA you almost always need a reference point, to get a feeling if the result is good or bad. Because there are many different options, assumptions and scenarios when creating the LCA models, that you have to be careful, when comparing different results to not encourage false conclusions.

Technical barriers: While undergoing research and development of this solutions, which technical barriers did you come across which are still needed to overcome before implementation?

- Not really applicable for LCA, although I see one of the main challenges in automatically generating standardized data in product development, that can then be used for LCA. The integration of LCA into the BIM process is currently heavily worked on.

Which policies or regulations in the EU-zone or specific countries are stimulating the application of this solution?

- EU Taxonomy (coupling cash flow to environmental requirements): https://finance.ec.europa.eu/sustainable-finance/tools-and-standards/eu-taxonomy-sustainable-activities_en. In Germany: QNG-Siegel (sort of a certification scheme like DGNB, LEED or BREEAM) is required when homeowners (builders) apply for a grant which also includes an LCA. (could not find an English version: https://www.nachhaltigesbauen.de/austausch/beg/). CO2-taxation: will propably include the environmental footprint not only of the use phase but of the production and end-of-life as well (in the future)

Limiting policies: Are there EU-wide policies or regulations or specific countries which are currently forming barriers for the solution to be implemented?

- The recently reworked law defining the energy standards for new buildings (Gebäudeenergiegesetz) does not include requirements regarding the environmental footprint (e.g. CO2 emissions) which is kind of a limiting policy or a missed chance.

Stimulating attitude: Consider the solution you are working on. Which stimulating attitudes of people will help push this solution?

- willing to support the fight against climate change (even if it means personal sacrifices)

Limiting attitude: Consider the solution you are working on. Which limiting attitudes of people will slow down the adaptation of this solution?

- fear of even more bureaucracy, more certificates and more complex approval procedures

Climate change: The climate is changing. This results in different average temperatures, extreme weather, extreme drought or flooding and other unforeseen effects. Consider the risks of climate change, how will this affect the implementation or use of this solution?

- I think LCA will become increasingly mandatory in product design and the building sector respectively.

Economic constraints: Which barriers do you see which will limit the adoption of this technology? Make a list and order them qualitatively from high to low.

- Full LCAs are expensive and time-consuming.
- Expert knowledge on the LCA as well as on the product side is needed.

Economic opportunities: Which economic opportunities can you list, which support the fast adoption of this technology? Mix general trends and specific examples where you are aware of.

- Considering mechanisms like CO2 taxation / EU taxonomy and so on, it probably will be financially beneficial to develop or use products with a lower environmental footprint.

Energy market: How does the metering, payment or availability of grid capacity influence the adoption of this solution? Describe in general terms of stimuli and barriers.

- not applicable

Customer segments: Which customer segments can be defined for this solution? These can be one or several customer segments which will be served. Think of building residents, building owners, MEP installation contractors, engineering firms, cooperations.

- Manufacuters, Design- and Engineering Teams, Construction companies

Value proposition: Describe the value proposition for this solution. Which is problem will be solved for the entity (customer) which is being proposed and how will it satisfy him/her?

- 1. Assessment of the current state
- 2. Reveal optimization potential
- 3. Proof of compliance with requirements

Channels: How would this proposition be delivered to the customer? Which channels of distribution are required to get this done?

- Communication channels (distribution of information);Sales channels (webshops; shops; sales portals);Education regarding environmental impacts in general;

Customer relationships: How will the relation with the customer be built and maintained during use? Will there be a service packages during the ownership phase / will there be a repair option / will there be regular updates?

- not really applicable

Revenue streams: If this solution would be brought to market, it will result in a revenue stream. This will work when the value proposition is successfully offered to customers. Revenue streams can be monetary, but revenue can also come in the form of benefit to others than the customer: enhancing biodiversity, adding social value, data collection, ...

- Ideally: A healthy and sustainable planet. But of course its also monetary, data collection, education/sensibilisation --> consumer awareness

Key resources: Specific resources to deliver the value proposition. List the required resources in a qualitative way.

- Because of the additional efforts foir LCA in product development or the planning process of building, it needs governmental requirements to perform those studies and thrive towards a more sustainabla consum

Key activities: Which would the activities be that people need to perform in order to deliver the value proposition?

- Expertise, education and governance

Key partnerships: Which partnerships are required to get the value proposition to market? These could be partnerships to outsource activities or resources required from others. Other partnerships could be knowledge networks or business clubs.

- Environmental impacts have to be considered within the product design. Therefore I think, that LCA experts need to work closely with manufacturers. Furthermore there has to be clear communication to the end user / consumer on the consequences of personal decisions.

Cost structure: Last but not least, define in a qualitative way the cost structure of the proposition. List the cost elements which are most significant in the solution.

- Pretty much like any other service

9.9 The integrated package of all above: an Integrated Energy System, using smart control and being implemented through a co-design approach.

Organization: BALTYCKA AGENCJA POSZANOWANIA ENERGII SP ZOO (BAPE) - Country: Poland

TRL 5: Technology validated in relevant environment

Organization: STICHTING JOINT IMPLEMENTATION NETWORK (JIN) - Country: Netherlands

TRL 3: Experimental proof of concept

Organization: WIRTSCHAFT UND INFRASTRUKTUR GMBH and CO PLANUNGS KG (WIP) - Country: Germany

TRL 6: Technology demonstrated in relevant environment

Organization: G. LIGEROS and SIA OE – PSYCTOTHERM (PSYCTO) - Country: Greece

TRL 7: System prototype demonstration in operational environment

Existing knowledge on markets: Have investigations been performed to map the possible market segments to which this solution can be applied?

By BAPE:

- Initial survey and review of simplified systems

By JIN:

- Yes

By WIP:

- Within the project there was some work done in WP4 and some here in WP7. Apart from that the idea of integrated energy systems for buildings is not new and there might be other market studies out there but I am not aware of any specific one.

By PSYCTO:

- The multi-source heat pump is a solution that is currently under development, while a few companies have already inserted this in the market (you can see the corresponding questionnaire for the companies). However, the integrated energy system is a solution that has to be applied as a customized solution for each case, depending on the disposable heat sources and the specific needs of the building.

Business models: Have business models been designed according to which this solution can be brought to market?

By BAPE:

- Preparatory stage, pilot projects have been considered

By JIN:

- No

By WIP:

- The work of WP4 and T7.1 were relevant but did not quite design specific business models.

By PSYCTO:

- No

Market mapping / business case: If 'yes' or 'other', please add information on the progress. If possible, include links to public information.

By BAPE:

- Integrated energy system concept, even in limited scope, has been new and revolutionary in Polish conditions. Big share of buildings, located beyond district heating and natural gas networks, has been heated with hard coal and oil as final energy source. Studies undertaken during the project implementation have revealed that IES could offer solutions of incorporating solar PV and heat pumps together with EMS for different types of buildings to phase out fossil fuels in feasible way. Introduction of IES in wide scale offers the only possibility to reach in longer perspective the fossil-free housing sector.

By WIP:

- In a previous project coordinated by WIP we developed business of using electricity demand flexibility. That project was targeted to large industrial users. It is not directly applicable, but in principle large buildings are large energy users, and an integrated energy system with proper BEMS and control would allow them to have some flexibility. If market allows they could use this flexibility in one of the business models proposed.

In the link below you would have to scroll down to find D2.4: Business models and market barriers

http://www.industre.eu/downloads/category/project-results

Competition: List the major competitors in the market deliver most the comparable technology / services.

By BAPE:

- The IES are emerging solutions at Polish market. Traditionally providers of technologies and services (PV, heat pumps, EMS) have been acting separately. On the energy management market the are companies offering BMSW. However recently there have been initiatives to offer integrated solutions of IES. Major competitors shall probably emerge from providers of IES technology components, already practising some integration initiatives.

By JIN:

- For Integrated Energy System supply services there are several supplier organisations active within the market (See D4.1, Annexes for an overview). However, IES suppliers services are still a niche market in the built environment. Moreover, they often only offer a technology service, but not associated financial and social (stakeholder engagement) services.

By WIP:

- There is no specific one I have in mind. There will certainly be others out there offering integrated energy systems, i.e. combinations of different technologies for buildings. Especially the PV + heat pump combination will be popular (there seems to be even an example of a PVT plus heat pump (https://www.pv-magazine.com/2021/09/30/residential-pvt-heat-pump-from-the-netherlands/). But as we are a publicly funded project, with an overall concept we promote aiming to decarbonise energy for buildings, I would not see others operating in the space as competitors but as potential collaborators.

By PSYCTO:

- Regarding the heat pumps of the integrated system, the following competitors have introduced products in the market:
  - flexoTHERM by Vaillant (https://www.vaillant.co.uk/homeowners/products/the-flexotherm-multi-source-heat-pump-22464.html)
  - Mitsubishi (https://les.mitsubishielectric.co.uk/products/commercial-heat pumpsand-chillers/commercial-heat-pumps/ecodan-crhv-monoblocgroundwater-source-heat-pump-system)
  - Better Planet, UK (https://www.betterplanet.co.uk/multi-source-heat-pumps)
  - China Palm, China (https://www.china-heat pump.com/category/heat-pumpproducts/multi-source-heat-pump/)

Highly compatible for

- Offices (commercial or governmental, including mixed-use) (by all partners)
- Residential (single family house) (by BAPE)
- Residential (multi-family apartments) (by JIN, WIP, PSYCTO)
- Public buildings (e.g. civic buildings, educational or cultural buildings) (by JIN, WIP, PSYCTO)

Low compatibility for

- Residential (single family house) (by JIN and PSYCTO)
- Residential (multi-family apartments) (by BAPE)

Are there requirements to the building skin energy performance in order to adopt this technology?

By BAPE:

- Yes, the quality of building skin energy performance influence the performance of this technology.

By JIN:

- No, system can be applied independent from building skin energy performance

By WIP:

- Yes, the quality of building skin energy performance influence the performance of this technology.

By PSYCTO:

- Yes, the quality of building skin energy performance influence the performance of this technology.

List 3 attractive advantages of the solution

By BAPE:

- Properly implemented IES following building thermorenovation shall bring energy savings to building users and protect them against price increase of energy from fossil fuels.

- Lower use of fossil fuels – hard coal and oil – shall reduce local emission and shall improve air quality.
- Additionally, thermal comfort in buildings shall be improved.

By JIN:

- Full service IES solutions tailored to specific building types, that are preceeded by advisory/service work on financing and stakeholder engagement/co-design can:
  - reduce transaction costs
  - enhance social acceptance of new technologies/solutions
  - will aid with sensible financial engineering (sound financial planning)

By WIP:

- Low carbon emissions and savings of (expensive and imported) fossil fuels
- Low operating costs
- Offering higher security of supply and independence from energy price fluctuations

By PSYCTO:

- Smart control of the system that predicts the most efficient heat source, which leads to improved performance of the system and to reduced operation cost.
- Eco-friendliness of the system, combining multiple RES technologies, with no on-site emissions).
- Very limited maintenance.

List 3 challenges of the solution

By BAPE:

- The biggest challenge, especially at the initial stages on IES implementation can be difficulties in integrating individual solutions.
- Costs of necessary building thermorenovation are high, funds are not easily available especially that part of end-users will be from low-income families.
- Implementation of IES will require training of installers and future support of OandM staff.

By JIN:

- Full service IES solutions tailored to specific building types, that are preceeded by advisory/service work on financing and stakeholder engagement/co-design are:
  - time consuming (and can also be costly if initial committment of involved stakeholders is low)
  - difficult to manage as decision-making is highly complex
  - demanding for the IES service company without having ex-ante certainty of a full service contract (they invest in acquisition, but stakeholders still may decide to switch to another IES supplier)

By WIP:

- Quite complicated meaning potentially high requirements for adjustments and maintenance.
- Probably high investment cost
- Each installation needs tailored design and dimensioning

All three challenges listed above is the reasons than in question 10 I ranked the single-house as the least attractive market

By PSYCTO:

- A well dimensioned system can lead to significant operation cost savings, but the components estimation and selection needs to be precise.
- Select the right control/operation strategy, which leads to the appropriate heat source selection and leads to increased efficiency.
- Issues regarding the peak demand, as the heat pumps are connected to the electricity grid.

Technical barriers: While undergoing research and development of this solutions, which technical barriers did you come across which are still needed to overcome before implementation?

By BAPE:

- Separate technologies suited for Polish market (without advanced ones, like magnetocaloric heat pump or PV-T collectors) are available. However integration together with EMS can be a challenge. Some development and innovations are needed taking into account local conditions, available technologies, status of the service providers and future operation and management. Direct transfer of technology from better developed market cannot be a solution.

By JIN:

- Technical barriers for individual technologies are often present, but solvable. Barriers for a set of linked or integrated technologies are more challenging as often multiple component suppliers are involved. Ensuring proper functioning of the entire technological system (combination of insulation and energy installations) faces barriers (coordination, blame-shifting between different suppliers, etc.)

By WIP:

- The control system probably needs more work before it is ready for mass deployment

By PSYCTO:

- For the integrated system, possibly VITO that deals with the control of the system, could contribute.

Stimulating policies: Which policies or regulations in the EU-zone or specific countries are stimulating the application of this solution?

By BAPE:

- Separate solutions are partly supported by Polish and EU funds. Simple integrated solutions are supported by a financial scheme for single family houses and shall serve as the example for multi-family houses and other sectors. Polish environmental and future EU funds shall play stimulating role in implementing of IES.

By JIN:

- A broad range of technology specific incentive/policies/regulations is already in place. Individual technologies are stimulated. Only a few schemes require at least two or more different energy saving measures to be implemented as an eligibility criteria. However, individual rules/regulations/incentives are often not serving the implementation of an IES system. As a result, end-user groups have to plough through an entire eco-system of regulations/incentives to be able to figure out what's financially optimal for them, and for which individual schemes to apply. (i.e. lack of integrated policy framework, or lack of clarity on 'policy complementarity')

By WIP:

- Any measures taken to deal with the current energy crisis will probably support the move towards cleaner solutions and as such overall positive for integrated energy systems like the ones promoted by RES4BUILD.

By PSYCTO:

- There is no clear legal framework regulating the application of the integrated solution. However, EU promotes the RES technologies as individual components of the system. For the heat pumps the following regulations have been proposed:
  - Directive 2009/28/EC
  - JRC, Renewables in the EU: the support framework towards a single energy market EU countries reporting under Article 22(1) b, e and f of Renewable Energy Directive, vol. 22, no. 1. 2017. (https://e3p.jrc.ec.europa.eu/sites/default/files/documents/publications/presentation_jrc110415_1.pdf)
  - Energy Performance of Buildings Directives (https://epb.center/epbstandards/energy-performance-buildings-directive-epbd/)

Limiting policies: Are there EU-wide policies or regulations or specific countries which are currently forming barriers for the solution to be implemented?

By BAPE:

- In Poland, there are no policies simulating jointly energy efficiency and conversion from coal to RES in buildings. Some introduced policies over recent years, like prosumer scheme, have been restricted by powerful power and coal sector. Regulations allowing for supporting policies, like energy cooperatives and communities have been delayed and limit development of local and individual initiatives.

By JIN:

- Most EU-wide policies (Directives) are at the basis of (updated) member state legislation and policies, which in turn result in a mixture of policy instruments (incentive schemes) to support reaching a specific (national) target. The policy mixes, and individual policy instruments in each EU member states are rarely checked for complementarity, and in some cases are even conflicting.

By WIP:

- Most of the support schemes for renewable energy systems could be listed under question 15. However, they can also work against integrated solutions. For example when there is a subsidy (i.e 2000 euro paid to a household that puts PV on their roof) an industry with standardised offers develops around that - there are companies offering to take over the subsidy paperwork and deliver and install PV in the houses. Similar with heat pumps. Asking any supplier to design an optimal integration of more than one technologies increases the transaction cost and is not a priority.

By PSYCTO:

- No.

Stimulating attitude: Consider the solution you are working on. Which stimulating attitudes of people will help push this solution?

By BAPE:

- Educational and awareness rising campaigns are necessary to stimulate initiatives towards will result in reduction of energy use and in lower costs of heating. implementation of IES. End users shall be convinced that conversion from traditional heating to IES. Thermal comfort in buildings and convenience of leaving will be higher. Communes elaborating their heat supply plans shall stimulate introduction of IES in renovated and new buildings.

By JIN:

- Perseverance and determination, as complex multi-stakeholder decision-making processes can take a long time, and can cost money even well before the actual IES investment decision is made.

By WIP:

- Thinking of larger newly developed buildings (like offices and apartment blocks) possibly the main driver will be the added value the green credentials will offer when selling or renting out the development.

By PSYCTO:

- Willing to reduce the global warming and on-site emissions.
- Willing to support the energy transition.
- Willing to incorporate cutting-edge technologies.

Limiting attitude: Consider the solution you are working on. Which limiting attitudes of people will slow down the adaptation of this solution?

By BAPE:

- Conversion from traditional heating systems to IES can meet sceptical approach of end users. The fear of unknown, with necessary capital expenditures can be a limiting factor when introducing IES. Some lower-income end users already facing energy poverty shall be supported and convinced consider the new alternative.

By JIN:

- fear of change, uncertainty of outcome (i.e. may signal need for energy performance contracts.

By WIP:

- The main issue initially will be the (perceived) risk of adopting a new solution, especially a complicated one

By PSYCTO:

- fear of the system complexity
- fear that there is need for buildings interventions (e.g. change radiators or improve insulation, incorporate a PVT collector, etc)
- fear that many technicians are unaware of more complex systems

Climate change: The climate is changing. This results in different average temperatures, extreme weather, extreme drought or flooding and other unforeseen effects. Consider the risks of climate change, how will this affect the implementation or use of this solution?

By BAPE:

- Conversion of building heating from fossil to IES can be climate neutral. Warmer winters shall help while implementing low-temperature heating systems. Additionally occasional need of cooling during summer can be covered by reversible heat pump supplied from own PV installation.

By JIN:

- Answer strongly depends on the local geophysical conditions of where the building is located. But in general, increasing extreme rainfall periods combined with prolonged droughts periods will have an impact on the built environment. In lower lying areas (in The Netherlands) dry conditions are a major cause of soil subsidence, while extreme rainfall can also cause (river) flooding. Both aspects have an impact on the implementation of IES solutions. For example, aside from the need to focus on efficient energy systems and buildings, there may also be a need to focus on / invest in structural reinforcement of building foundations (soil subsidence) or more localised water management (floodings).

By WIP:

- The solution will be dimensioned taking into account historic data. A changing climate might lead to different levels of irradiation (i.e different PV and solar thermal outputs) and different level of demand for heating and cooling. The final outcome might be that the dimensioning of the system will not be ideal.

By PSYCTO:

- The smart control needs to select the most appropriate heat source to lead to improved performance. The increase of ambient temperature increases the performance of the air-source operation.
- The building insulation and size in combination with the climate conditions could increase the heating demand, leading to reduced system performance.

Economic constraints: Which barriers do you see which will limit the adoption of this technology? Make a list and order them qualitatively from high to low.

By BAPE:

- The biggest economic constrain are high capital expenditures, including necessary passivation of a building and introduction of IES together with EMS. Talking into account relatively low costs of present coal heating, savings after conversion to IES would not allow for short repayment of investments.

By JIN:

- There is an inadequate business model for offering IES services to the market. While integrated technological concepts exist, the socio-economic conditions for IES investment decision-making by hetergeneous multi-stakeholder groups are often still poor. E.g. how to finance in a collective IES system in a multi-family building knowing that not all? Building-linked financing contracts, and energy performance contracts can help. At the same time, the current economic conditions (labour shortages in many professions) and the spiking energy, commodity and building material prices are cuasing a slowdown in the scale up of IES.

Aside from that the high inflation rates, not only affect the energy prices, but also building material and food prices. The higher this general price increases (people / companies will start eating in their financial reserves), the lower the capacity to invest will become.

By WIP:

- High investment cost

By PSYCTO:

- Increased cost of electricity because of the global situation of energy inconsistency.
- increasing cost of raw materials for the system manufacturing because of the global geopolitical situation.

Economic opportunities: Which economic opportunities can you list, which support the fast adoption of this technology? Mix general trends and specific examples where you are aware of.

By BAPE:

- Economic opportunities are expected to be noticed by local communities. Money initially spent for fossil fuels will stay at a local market. Necessary works on building renovations and implementation of IES will be performed by local contractors. The process will be especially beneficial for active MSMEs (micro, small and medium enterprises) and investment process shall boost local employment and communities.

By JIN:

- Increasing (or structurally high) energy prices for electricity and heating are a primary driver for stakeholders wanting to invest in IES,
- In general, many subsidy/support schemes for non-integrated energy investments have been avaibable throughout the years, however often these schemes had a limited budget (i.e. ran out of budget) after which the people who applied for the scheme will have to wait for a longer time to make the IES investment (stop-go policy).

By WIP:

- Raising natural gas and oil prices and uncertainty about security of supply

By PSYCTO:

- There are no policies and economic opportunities for the integrated system, however there are opportunities for the RES technologies, such as heat pumps, PVT, etc. Such opportunities for the heat pumps are the following:
    - https://www.gov.uk/domestic-renewable-heat-incentive
    - https://www.greenmatch.co.uk/heat-pump/heat-pump-grant
    - increasing fossil fuel prices
    - The Regulatory Assistance Project (RAP) has developed a report aiming to to offer guidance on how to improve the EU’s Fit-for-55 package to encourage greater use of heat pumps (https://www.raponline.org/knowledge-center/the-perfect-fit-shaping-the-fit-for-55-package-todrivea-climate-compatible-heat-pump-market/)

Energy market: How does the metering, payment or availability of grid capacity influence the adoption of this solution? Describe in general terms of stimuli and barriers.

By BAPE:

- Presently distribution networks in Poland are hardly prepared to accommodate IES in connected buildings. Installation of smart meters has not been implemented in wider scale. Quality of low-voltage grid is low and operators are not ready for mass connection of prosumers. Prosumer scheme has been recently changed to be less-favourite for end users.

By JIN:

- Metering: The Netherlands already has installed most of the required smart meters. Net metering will be gradually phased out as per end 2023, which will result in a reduced payback time of new solar pv installations. Grid congestion is already observed in many regions throughout the country in different power grid (sub)systems. Policies for collective IES heating systems may require regulatory mandates to a) disconnect people from the gas grid, or b) to mandatory connect peoples' houses to a disrtict heating system.
- Energy poverty has become a real issue in the past 8-9 months.

By WIP:

- Time of use payments might help the adoption when introduced as they will encourage systems with built-in flexibility

By PSYCTO:

- The possibility of malfunction at times of peak demand of electricity could be a problem for heat pump systems integration. Careful planning and infrastructure investment will be required to meet the additional demand for electricity.

Other: Which influences are relevant for implementation of this solution and have not been discussed before?

By BAPE:

- Readiness of the banking sector to support combined measures, with long payback time.

By PSYCTO:

- There is need for PVT operating at higher temperatures (in case that ambient temperatures get higher). Also, there is need for 4th generation refrigerants or even natural refrigerants to be employed in order to reduce the impact on greenhouse effect and ozone depletion.

Customer segments: Which customer segments can be defined for this solution? These can be one or several customer segments which will be served. Think of building residents, building owners, MEP installation contractors, engineering firms, cooperations.

By BAPE:

- In longer run end-users from all segments can be attracted by IES. However initially consumers from commercial and business sectors are the natural target groups. Public buildings and residential sector are the next candidates. Firstly, pilot solutions shall be implemented and publicized.

By JIN:

- All building types and all multi-stakeholder customer segments can (in princniple) benfit from an integrated IES approach.

By WIP:

- Developers of large buildings, mainly offices and apartment blocks

By PSYCTO:

- Building owners
- MEP installation contractors
- Engineering firms constructing buildings

Value proposition: Describe the value proposition for this solution. Which is problem will be solved for the entity (customer) which is being proposed and how will it satisfy him/her?

By BAPE:

- Conversion to IES shall bring in longer run energy and cost savings. Greening of facility image will be achieved immediately. Operation of own energy system will be easier, without problems with purchasing fossil fuels and less polluting environment.

By JIN:

- One-stop (shop) service for IES systems to become climate-energy proof before 2030 (or 2050).

By WIP:

- A building where the energy is supplied with the environmental impact being minimised. Similarly the recurring monthly cost for the building users is kept at a minimum and is decoupled from the fluctuating prices of fossil fuels.

By PSYCTO:

- Reduced heating cost (for owners/residents)
- Very limited maintenance (for owners/residents)
- Eco-friendly profile (for owners/residents/engineering firms)

Channels: How would this proposition be delivered to the customer? Which channels of distribution are required to get this done?

By BAPE:

- Sales channels (webshops; shops; sales portals);The complex IES solutions shall be supported by professional support, for example by local, communal one-stop-shops. This will allow end-users to select proper technical solutions, means of financing and potential contractors. ;

By JIN:

- Multiple / undefined. These could most likely come in the form of ome sort of intermediary organizations. Part of a new market model/system. ;

By WIP:

- Communication channels (distribution of information);engineering companies;

By PSYCTO:

- Communication channels (distribution of information);

Customer relationships: How will the relation with the customer be built and maintained during use? Will there be a service packages during the ownership phase / will there be a repair option / will there be regular updates?

By BAPE:

- Service packages shall be offered especially during the initial period of the IES implementation. OandM staff shall help end-user in achieving high effectiveness of the IES system and later shall be available for routine servicing and in case of malfunctions.

By JIN:

- A good IES solution should pre-, during, and post construction customer relations. Not all IES system suppliers have such modus operandi for after sales service.

By WIP:

- There will be different levels:
  - Overall system design is mostly a once-off job
  - BEMS system mostly a once-off job but must be available for troubleshooting updates etc - possibly also a service contract can be considered when a full package of active management is required updating regularly with latest energy prices, forecast services etc.
  - For all components the manufacturers should offer guarantees, service and maintenance (but this could be managed centrally through the engineering company to make it simpler and more attractive for the customer?)

By PSYCTO:

- The reduced heating and cooling cost of the customer is the best way to build a trustworthy relationship with the user/customer. The smart control of the system leads to an improved efficiency and reduced cost of the whole system.
- Moreover, the maintenance of the system (cleaning of the PVT, maintenance of the heat pump, etc.) and the control adjustment during regular services would lead to even better performance.

Revenue streams: If this solution would be brought to market, it will result in a revenue stream. This will work when the value proposition is successfully offered to customers. Revenue streams can be monetary, but revenue can also come in the form of benefit to others than the customer: enhancing biodiversity, adding social value, data collection, ...

By BAPE:

Revenue stream for a customer will result from lower spending on fuels and energy. Some purchasing of electricity will be needed but will be lower than initial final energy use. Additionally, introduction of IES will result in better air quality.

By JIN:

Revenue streams can come from providing (current) classical services, but other (eco-)system services are rarely rewarded within the Dutch market.

By PSYCTO:

- Development of a new market for the company.
- Enhancement of the eco-friendly profile of the company.

- Development of a trustworthy profile for the company, with a significant social value.
- Enhancement of the high-tech profile of the company.

Key resources: Specific resources to deliver the value proposition. List the required resources in a qualitative way.

By BAPE:

Introduction of wide-spread IES solutions will require much bigger supply of components and presence of qualified contractors offering complex solutions. Both hardware and IT will be needed, offered in reliable packages. Contractors' staff shall be trained in advance. This aspect will need time to be finalised.

By JIN:

skills, capacities and (financial) resources to not only invest in the IES technology, but also up-front invest in good information collection and decision-making within multi-stakeholder processes (i.e. before making an investment, there needs to be consensus..

By PSYCTO:

- Availability of low GWP and ODP refrigerants for the muti-source heat pumps
- Availability of components based on the sizing that has been designed.
- Well-educated personnel for the appropriate design of the control system.

Key activities: Which would the activities be that people need to perform in order to deliver the value proposition?

By BAPE:

- Education and awareness rising of consumers is essential for the success of this innovatory heating and energy system. Energy staff in communes shall be trained to understand the new heat and energy systems for housing and to advise later proper solutions to end users. Growing demand shall stimulate the market of supply and services related to IES.

By JIN:

- Guiding / monitoring the preparation, implementation, and post-implementation process.

By WIP:

- I am not so sure if I have anything more to offer for questions 28-32. For whatever it is worth I think that the main steps needed after the end of the project have mostly to do with:
  - A design tool/approach (building on task 3.1 work) that will help companies like ARUP develop integrated solutions to suggest to customers.
  - A robust and flexible BEMS that can work smoothly on any building optimizing performance while offering to the building users simple but powerful control options
  - Strong demonstration projects in full scale that will be used to convince developers that it is a tried and tested solution with low technological risks.

By PSYCTO:

- guiding the process that all the sources are well designed and operating

- well-established components
- testing, commissioning, maintenance

Key partnerships: Which partnerships are required to get the value proposition to market? These could be partnerships to outsource activities or resources required from others. Other partnerships could be knowledge networks or business clubs.

By BAPE:

- Integrated solutions are new at Polish market, both for end-users and service providers. Partnerships of companies involved in IES development and implementation shall result in better market offer, better quality and lower prices in longer run. This shall stimulate bigger demand. End-users shall be supported by local communities, at preparatory stages and systems implementation.

By PSYCTO:

- Installation of each RES technology of the integrated system (PVT, geothermal source, heat pump, etc.)
- Partnerships aiming to expand the information network.

Cost structure: Last but not least, define in a qualitative way the cost structure of the proposition. List the cost elements which are most significant in the solution.

By BAPE:

- IES shall be offered at the Polish market after reaching required effectiveness of operation, integration and competitive prices. Costs of building retrofits could be a decisive factor for end users. Boreholes of ground heat pumps have big share of the complete IES solution and this cost shall be reduced during dissemination period of IES.

By PSYCTO:

- Raw materials for each heat source technology (piping, compressor, heat exchangers, expansion devices)
- Electronic equipment for the control of the system (electric panel, PLC, instrumentation)

10 Appendix L: Data model

10.1 Introduction

The significant amount of information in the market- and EU analyses is summarized in a data model. This model is framework for translating policies, local incentives, and socio-economic aspects into applicable information. This may be used by businesses, local authorities, or energy communities to help decision-making.

It includes the data from 8 countries and overall EU-policies. As part of T7.2 in the RES4BUILD project it is a proposed way of working with a status quo of data, helping the project team to convert quantities of data into conclusions. Working towards future implementation, the roadmap shall explain further development.

This appendix explains the information flow into- and from the model and shows examples, rather than the full model.

10.2 Information flow

Input

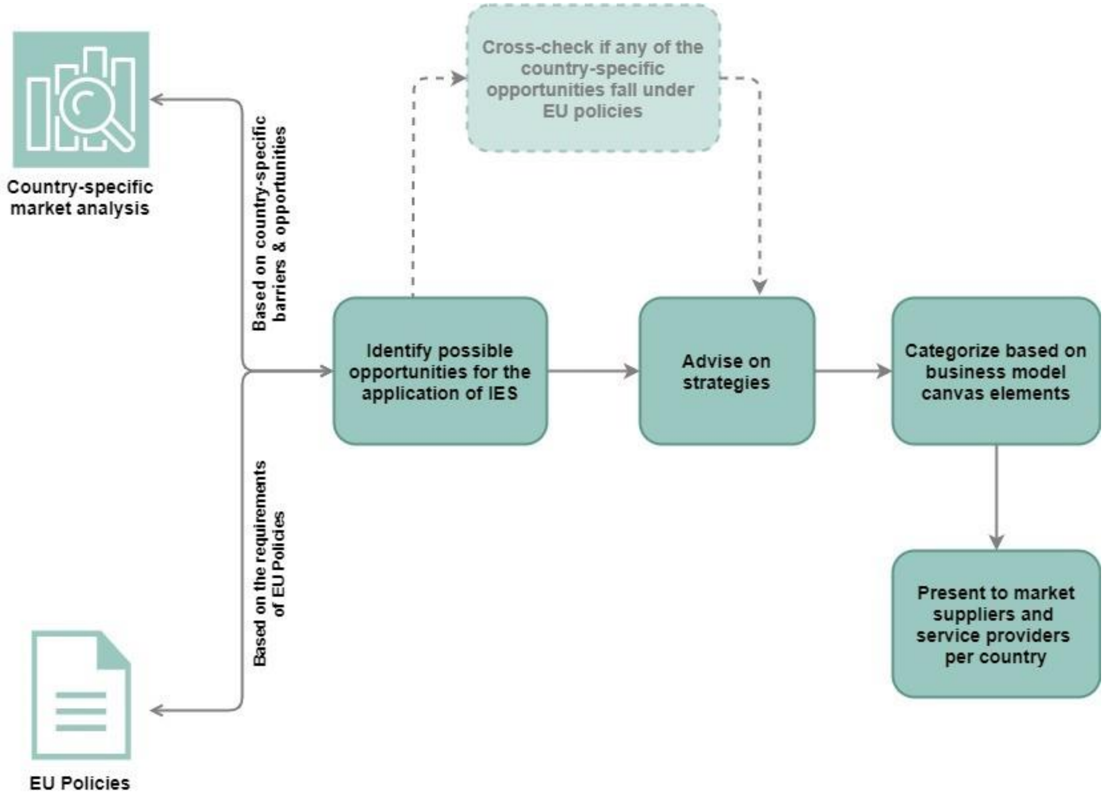
Two sets of inputs are used in this data model:

1. Appendix I EU policy context explains relevant policies at EU level. To comply with these policies, specific measures must be taken.
2. Based on the country-specific market analyses, opportunities and barriers are identified which can be related to different aspects including cultural and socio-economic, building codes and regulations, or the energy market rules and tariffs.

Output

Using the two sets of input data, possible opportunities for the application of Res4Build are identified which are then translated to advised strategies for the IES business model:

1. Based on the measures required by the EU policies, possible opportunities for the application of Res4Build are identified. When advising on a strategy based on EU policies, the strategy is applicable to all the 8 countries. If specific information related to these policies is available per country, they are reflected in the section dedicated to the country's market analysis.
2. The market opportunities and barriers are translated to possible opportunities for the application of Res4Build which are then included as advised strategies for the IES business model.



10.3 Data

Information in the data table is organized in the following sections:

Column A	Categorization per Business Model Canvas segment.
Column B	Further specification per theme
Column C	Advised strategy for IES Business Models: this summarizes both the EU-regulation study and the country-specific conclusions. This is to be applied for setup of future business models and used as 'program of requirements' (PoR).
Column D	Explanation: providing argumentation on why aspects should be part of the PoR, based on the aggregated info from policies & regulations. This includes both aspects from EU-level and country level.
Columns E-Y	Cross-reference to the applicable EU-regulations. This is supportive to review which regulations interact.
Columns Z-AG	Cross-reference to the applicable local findings per country. The link is based on information from the Market Analysis appendices.
Column AH	Country specific details.

10.4 Abbreviations

For the EU-regulations, the following abbreviations are applied:

EGD	European Green Deal
ECL	European Climate Law
FF55	Fit for 55 package
CTP	2030 EU Climate Target Plan
ETS	Emissions Trading systems
ESR	Effort Sharing Regulation
RED	Renewable Energy Directive
EPBD	Energy Performance Building Directive
EED	Energy Efficiency Directive
ET	EU Taxonomy
CEEP	Clean Energy for all Europeans Package
RW	Renovation Wave
EAS	European Adaptation Strategy
ECEAP	EU Circular Economy Action Plan
SCF	Social Climate Fund
iBR	IBRoad
EDHR	EU District Heating Regulation
REPE	REPowerEU
FGAS	F-gas regulations
SCC	Sustainable Carbon Cycles

10.5 Examples

Example 1 – creating the value propositions

When targeting the total EU as a market, the data model can be used to define the relevant value proposition for an Integrated Energy System. The data model highlights those elements from regulation impacting the decision. Below example shows some of the advised strategies. In this case, specifying phasing (first renovation, then IES), setting targets and defining the key parts of the proposition.

Business Model Canvas Segment	Theme	Advised strategy for IES business model	Explanation
Value Propositions	Property	first improvement of thermal properties, then IES	As per the efficiency of investments in energy systems, the current GHG emissions of energy systems and per the social goals, the correct strategy is to start with improvement of thermal properties in buildings and secondary invest in innovative systems. Ireland: energy savings potential through energy efficiency improvements is largest in the residential sector. Poland: A significant portion of the buildings are characterized by low energy efficiency and will require thermal modernization in the coming years. Revitalization Law introduces new solutions that allow, among other things, local governments to play a more active role in carrying out renovations and thermal upgrades in buildings. In Spain, incentives help to reach the thresholds required under the PRTR is to act on the building envelope, installing insulation in both facades and roofs, and
Value Propositions	GHG emissions	Include annual term targets for gradually reducing GHG emissions, including production emissions. Per member state	The ETS introduces allowances that stimulate gradual reduction of GHG-emissions in a cost-effective manner. The ESR sets annual targets per sector. In Ireland: Under ETS requirements, emissions from electricity generation must be reduced by 43% by 2030, relative to 2005 levels. By 2030 Ireland plans to incorporate renewable energy systems to its energy infrastructure. This provides a significant window of opportunity to the RES4BUILD's market
Value Propositions	Renovation	Make highly efficient renovation (cost-optimal towards NZEB) of building skins and enhancement of energy efficiency a key part of the proposition	The ESR requires a broad approach to decarbonization, including requirement energy efficiency renovations to incorporate energy saving measures. This is also included in RED, as mandatory requirement for the use of renewables. To be targeted to projects undergoing major renovation requirements, as per EPBD.

Example 2 – targeting customer segments

When targeting specific customer aspects per country, the model shows which are relevant. In this example for the Netherlands, where energy poverty is also seen as a risk in the residential sector. For non-residential it shows opportunities to target those business which are e.g. EEU auditable. And if measures are applied, it shows that reports & certificates for completed upgrades are valuable in the market.

Business Model Canvas Segment	Theme	Advised strategy for IES business model	Explanation	NL
Customer Segments	People	Target countries or regions first with relatively high energy poverty. This should be done through promoting consumer empowerment.	The new EED includes measures to boost renovation in a way that benefits society in terms of addressing energy poverty and strengthening consumer empowerment. In Ireland: significant support from the government in terms of grants and free energy upgrades to counter the risk of energy poverty. Poland: Costs of house insulation - replacement of windows, ceilings, doors, wall insulation - are two or even four times higher in 2022 than 2021. This situation will lead to increased energy poverty.	x
Customer Segments	People	Target auditable companies and offices	The EED Energy Audit is an obligation arising from the European Energy Efficiency Directive (EED). The energy audit provides a detailed overview of all energy flows within the company and also insight into the possible savings measures and the expected effects thereof. This includes the energy consumption of buildings, industrial processes, and installations, including transport and heat. Auditable companies must carry out an energy audit every 4 years.	x
Customer Segments	Reports & Certificates	In office buildings, Include system requirements for improving the energy performance of technical building systems	These requirements focus on the energy performance, the adequate dimensioning, installation and adjustment, and the adjustability of technical building systems. The system requirements apply to systems for: - space heating and space cooling - ventilation - hot tap water - built-in lighting - building automation and control systems: Non-residential buildings with heating or air-conditioning systems with an output of more than 290 kW must be equipped with a building automation and control system (GACS) from 2026.	x

Example 3 – impact of policies

The model is useable to review the impact of policies on the business model. In this example it shows some of the Fit for 55 consequences, which in this case translate predominantly in the financial aspects of the model: including GHG emission pricing, providing financial support to vulnerable households and to include subsidies. The targets are helpful as guidance in the value proposition, it helps to aim for higher performance of the integrated technologies.

Business Model Canvas Segment	Theme	Advised strategy for IES business model	Explanation	FF55
Revenue Streams	People	Provide financial support to vulnerable households	The Social Climate Fund is part of the "social fund" pillar of the Fit for 55 Package and aims to finance temporary direct income support for vulnerable households that results from increased energy costs arising from EU energy transition policies. The fund aims to alleviate this financial burden through redistribution. It will be partly financed by revenues generated as part of the EU Emissions Trading Scheme.	x
Value Propositions	Policy	Adopt the target of additional reduction of energy consumption of 9% by 2030 compared to 2020. RES4BUILD should aim towards a higher target.	The new EED would require EU Member States to collectively ensure an additional reduction of energy consumption of 9% by 2030 compared to 2020. This proposal responds to the European Climate Law (specifically the 2030 objective that mandates a 55% net greenhouse gas emission reduction) and will be introduced under the Fit for 55 Package. This proposal is interlinked with many of the other policies proposed under the Fit for 55 Package.	x
Revenue Streams	GHG emissions	Include GHG emission pricing in the business model	The Fit for 55 package includes a number of instruments, such as carbon pricing, regulation, changes to standards and creation of funds. Member states, such as Germany have included this in their 2022 Immediate Action Plans.	x
Revenue Streams	Subsidies	Include use of subsidies, local incentives or funds as part of the business model.	The Fit for 55 package includes a number of instruments, such as carbon pricing, regulation, changes to standards and creation of funds. All local markets have subsidies in place.	x