RES4BUILD

RENEWABLES FOR CLEAN ENERGY BUILDINGS IN A FUTURE POWER SYSTEM

KEY ACHIEVEMENTS

CONTENTS

RES4BUILD (2023) Deliverable 8.5 Knowledge Transfer Key Achievement Booklet - Public

This project has received funding from the European Union's Horizon 2020 research and innovation programme under Grant Agreement No. 814865 (RES4BUILD). This output reflects only the author's view. The European Climate, Infrastructure and Environment Executive Agency (CINEA) and the European Commission cannot be held responsible for any use that may be made of the information contained therein.

INTRODUCTION

Renewables for clean energy buildings in a future power system (RES4BUILD), is a four-year Horizon 2020 funded research and innovation project that started in 2019.

Coordinator's welcome

Over the last four years the team has been working hard to support the transition to a clean energy future, developing integrated renewable energy-based solutions and tailoring them to the needs of users and installers. The project aimed to increase the uptake of such solutions for heating and cooling in buildings.

This involved improving the performance and reducing costs of the most innovative components of the RES4BUILD solutions, including magnetocaloric and vapour compression heat pump technologies, PV/T collectors, borehole thermal energy storage and building energy management systems.

In parallel to the technical work, partners collaborated with end-users and other stakeholders in the Netherlands and Poland to explore the needs and challenges with respect to decision making and implementation of integrated energy systems in their building(s). This, together with a full life-cycle impact assessment of the integrated RES4BUILD energy system, and a market review, aims to pave the route to market for integrated energy systems.

The results are very encouraging, and we expect that in a refurbished multifamily building the RES4BUILD systems could deliver a significant reduction of CO_2 emissions compared to traditional solutions.

The following pages contain some of the key achievements and outcomes from the project. For more information please visit the project website (www.res4build.eu), where the outputs and reports are available to download.

Dr Michael Papapetrou

RES4BUILD Project Coordinator

WIP Renewable Energies

Renewables for clean energy buildings in a future power system

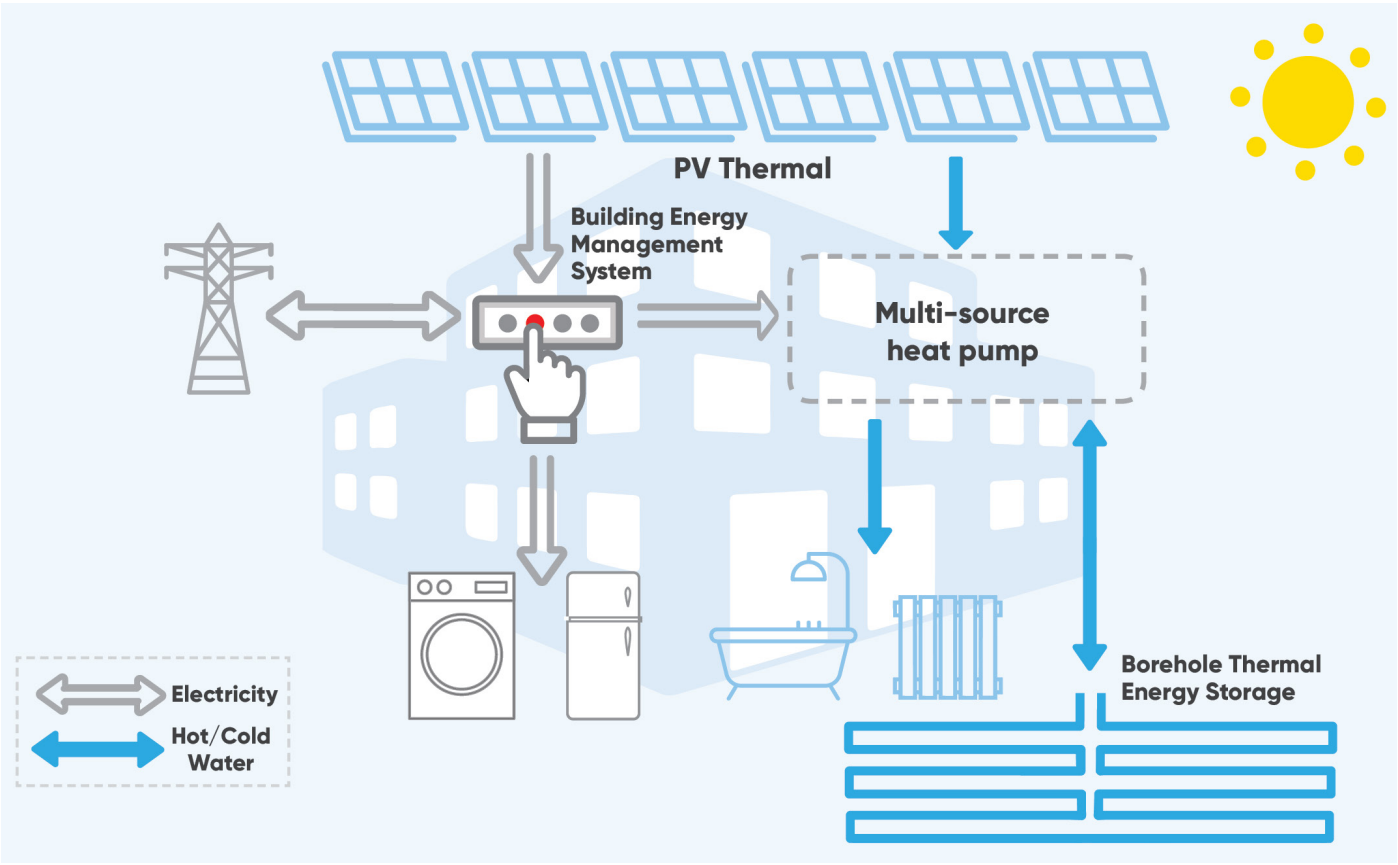
The Challenge

Decarbonising energy consumption in buildings is essential to achieving the EU energy and climate goals. While the use of renewable electricity in buildings has grown steadily, the uptake of renewable energy solutions for heating and cooling has been slower. This is due to several factors, including the greater variety of technological options and the varied needs of users and buildings.

Project Objectives

RES4BUILD aimed to decarbonise the energy consumption in buildings by developing integrated renewable energy-based solutions that are tailored to the needs and requirements of users and installers. The consortium's multidisciplinary team of experts worked to:

- Improve the performance and reduce the cost of the most innovative RES4BUILD components
- Develop tools for simulation, sizing and control, making optimal use of integrated energy systems and the flexibility of consumption
- Engage all relevant stakeholders in an interactive process to co-design integrated energy systems that suit current needs and future expectations.
- Test and validate various RES4BUILD solutions in different climates, namely at the Danish Technological Institute, Denmark and the National Centre for Scientific Research Demokritos, Greece.
- Pave the way for bringing the developed solutions to the market using rigorous life cycle assessments to measure their real impact, ensuring wide adoption.



The Technologies

A Magnetocaloric Heat Pump (MHP) uses the change in temperature when magnetising (heating) and demagnetising (cooling) magnetic material to build a heat pump.

A multi-source heat pump coupling the MHP to the evaporator of a vapour-compression heat pump, the latter of which employs a two-stage configuration.

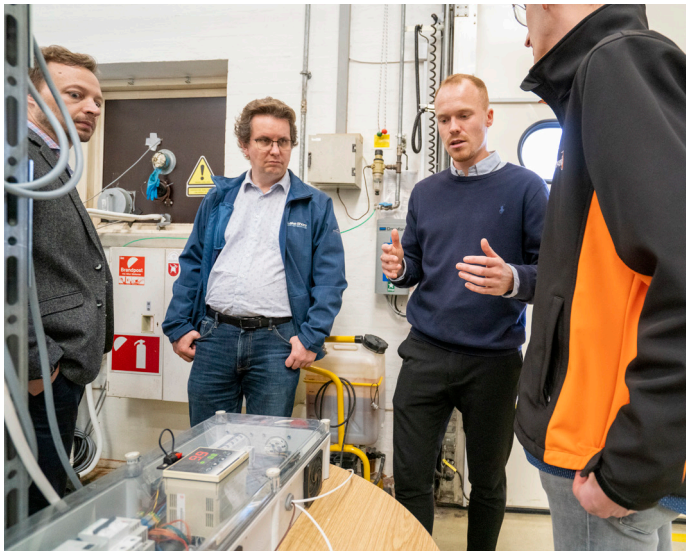
PV/T collectors that combine the features of standard PV panels and solar thermal collectors to produce both heat and electricity with a higher energy yield than separate collectors.

Borehole Thermal Energy Storage (BTES) that extracts heat from an array of boreholes during winter using a heat exchanger. The flow is reversed in summer months.

A Building Energy Management System (BEMS) to monitor the mechanical and electrical equipment in buildings, and using control software to optimise the system's operation to meet user-defined objectives.

Expected Impacts

- Solutions that reduce our dependence on fossil fuels for electricity, heating and cooling in buildings.
- Innovative components and technologies for increased performance in building systems.
- Best practice to approach renovations of energy systems in a more integrated and systematic way.
- Shared knowledge and innovative synergies with industry and other sectors.
- More efficient operation and optimised interaction with the grid, and thus a lower energy bill for European consumers.
- Social inclusion and an accelerated energy transition due to the co-design approach with various stakeholders.



TECHNOLOGY COMPONENTS

The RES4BUILD integrated energy system contains a number of innovative technological components.

- Photovoltaic Thermal Collectors to maximise heat and electricity that can be produced when space is limited.
- Multi-source Heat Pump, which combines magnetocaloric and vapour compression technologies.
- Borehole Thermal Energy Storage.
- Building Energy Management System.

Novel stationary concentrated photovoltaic-thermal solar collector

Scientific or Technological R&D Result

There is a need for a viable solution in the current market for stationary concentrating Photovoltaic-Thermal (PVT) collectors at locations with medium and low latitudes, where the solar radiation profile is more evenly distributed throughout the year. A newly symmetric reflector geometry has been suggested to replace the traditional asymmetric reflector geometry. This comes mainly from the symmetric solar radiation profile at medium and low latitudes but also due to the division of the focal line in two, which reduces material stress and limits the current and heat losses. To that end, a Compound Parabolic Collector reflector geometry that is typically used for solar thermal collectors with tubular absorbers has been optimised for stationary concentrating PVT solar collectors.

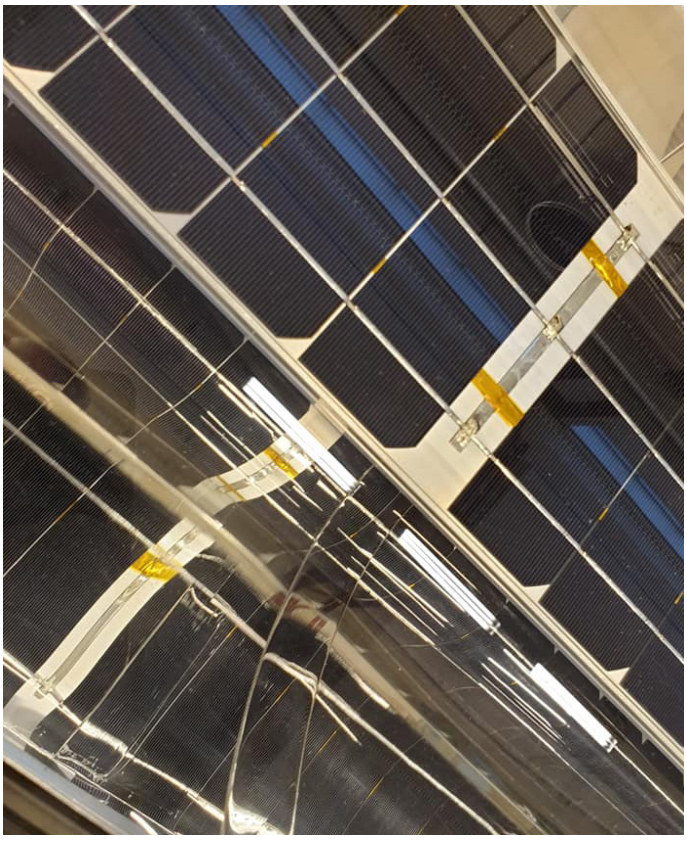
This technology is improved further by reducing the heat loss (heat output increase) and the cell operating temperature (electrical output increase). The receiver can include a novel H-Pattern design that minimises the distance between the cells and the cooling element (the receiver) which maximises the cooling effect, while avoiding thermal stress and maintaining cell longevity.

These developments will allow for an improvement in both electrical and thermal yields, and will enable decreased manufacturing costs of solar collectors.

The reflector geometry itself is now fully optimised. However the main goal of this technology is to be inserted in stationary CPVT solar collector which is currently in testing. R&D is expected to take two to three years, as the technology must be demonstrated and proven in the operational environment.

The receiver technology is currently being simulated and will require testing. As the technology is currently at TRL 4, this could take three to four years. It is expected that in 5 years, the CPVT solar collector will reach a TRL of 7/8.

Furthermore, a commercial production line for cost reduction in production of CPVT solar collectors with a manufacturing readiness level between 2 and 3 (i.e., manufacturing proof of concept developed) is expected at the end of the project. The developments will be protected by a patent application for the reflector geometry owned by MG Sustainable Engineering.



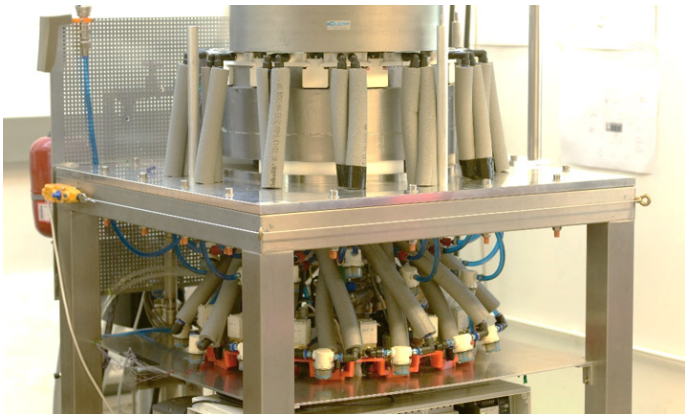
Additional Information

- João Gomes, MG Sustainable Engineering AB (joao@mgsust.com)
- Various publications, see: www.res4build.eu/results/publications

Lamination of iron plates for low frequency operation of large permanent magnet assembly

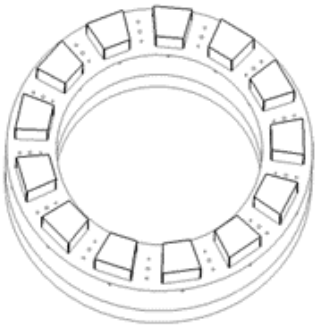
Scientific or Technological R&D Result

In the RES4BUILD magnetocaloric heat pump (MCHP) a large permanent magnet structure is rotated above a crown shaped steel ring. The magnetocaloric material is on top of the protrusions. When moving a magnet past a conductor, eddy currents are induced in the conductor. These dissipate as heat, in addition to creating a braking torque.



Severe effects of the eddy currents were experienced in the original version of the MCHP. The crown was solid, but the protrusions were laminated. It was assumed that the effect would be worst in the protrusion, and that lamination of the ring was not needed. Lamination is a common technique for reducing eddy currents and is conventionally done in transformer cores, where the frequencies can be very high. Laminations must be as thin as possible, and in transformer cores, they are often of the order of 0.1 mm.

The RES4BUILD MCHP will operate at low frequencies, about 0.5 Hz to 2 Hz, much lower than most other equipment. This raises the question of how thin the laminations must be made, and how much space for gluing can be tolerated. Through numerical modelling it was found that that the plates could be as thick as 4 mm, without having a significant impact from eddy currents. Also, it was found that an epoxy layer of 2 mm in total would only lead to a reduction in the field of less than 1%. On this basis, it was decided to proceed with building the ring from 13 parts, each consisting of 23 epoxied plates. This has shown that the requirements for lamination are fairly modest at low frequency.



This research will be used by DTU in further R&D activities. It can also potentially be used by other organisations involved in magnetocaloric research activities. Eventually it can be used by companies working on developing magnetocaloric heat pumps for the market.

Additional Information

- Christian Bahl, DTU Energy (chrb@dtu.dk)
- Dall'Olio, S., Masche, M., Liang, J., Insinga, A.R., Eriksen, D., Bjørk, R., Nielsen, K.K., Barcza, A., Vieyra, H.A., Beek, N.V., Bez, H.N., Engelbrecht, K., Bahl, C.R.H. (2021) Novel design of a high efficiency multi-bed active magnetic regenerator heat pump, *Int. J. Refrigeration* **132**, 243-254.
- Masche, M., Liang, J., Dall'Olio, S., Engelbrecht, K., Bahl, C.R.H. (2021) Performance analysis of a high-efficiency multi-bed active magnetic regenerator device, *Appl. Therm. Engineer.* **199**, 117569-12.

Operation and control of a magnetocaloric heat pump

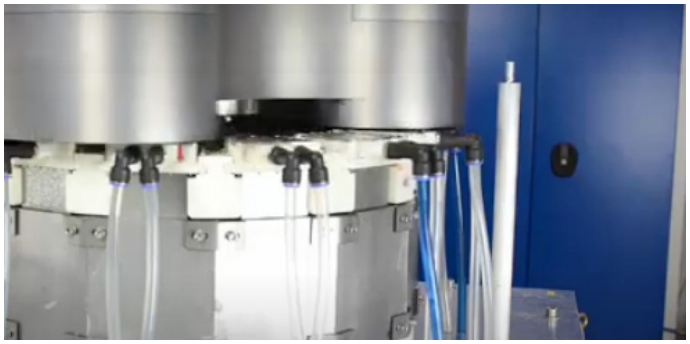
Scientific or Technological R&D Result

The RES4BUILD project is developing a magnetocaloric heat pump (MCHP) for heating applications; the first time a magnetocaloric device has been used for heating purposes. Previous magnetocaloric devices have in general been used for cooling applications. The two operate in a similar fashion. However, for magnetocaloric devices there is a difference in their testing and operation as a heat pump, compared to a refrigerator.

When operated as a refrigerator, conventionally the hot end is controlled by a constant temperature reservoir, while measured heating power is applied to the cold end. The temperature span between the ends is then reported as a function of the cooling power (the applied heating power). It is much more challenging to measure heating power than to measure the applied heater power for a heat pump. The method developed at Technical University of Denmark (DTU) is to have a fixed temperature heater at the cold end and a temperature control bath at the hot end. In this way, a fixed temperature span can be imposed. At the given temperature span, the cooling power is measured as the time average of the applied heater power. The heating power is then found by adding the cooling power and the work, where the work is the sum of the pumping power and the motor power for rotating the magnet.

Another novelty is the flow control system. Magnetic valves control the fluid flow in and out of each regenerator bed. This allows for a tuning of each bed, but also for an overall tuning of the system. By varying the opening time of the valves, it is possible to run the heat pump into a mode with a higher Coefficient of Performance, but a lower heating power, or vice versa.

This research will be used by DTU in further R&D activities. It can also potentially be used by other organisations involved in magnetocaloric research activities. Eventually, it could be used by companies working on developing magnetocaloric heat pumps for the market.



Additional Information

- Christian Bahl, DTU Energy (chrb@dtu.dk)

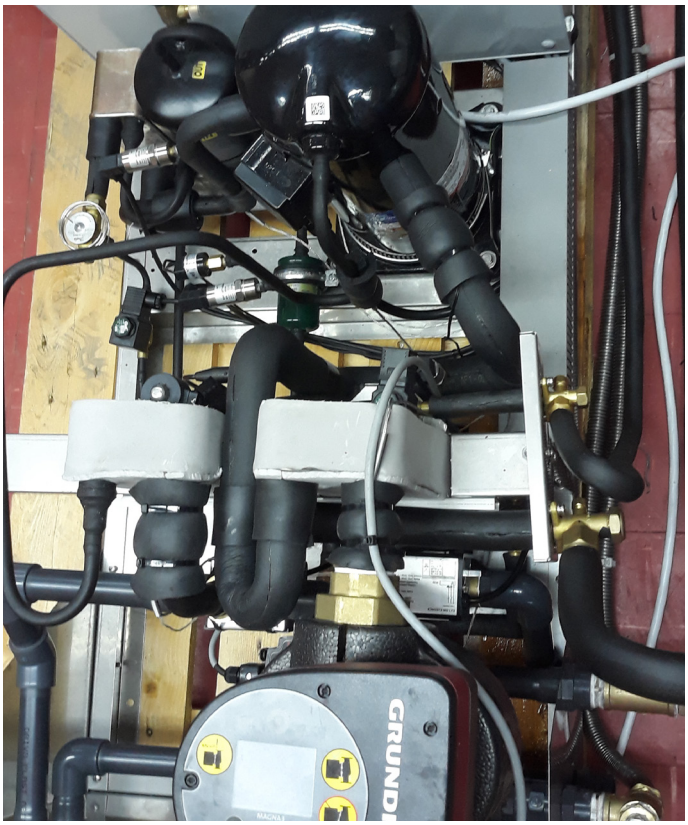
- Dall'Olio, S., Masche, M., Liang, J., Insinga, A.R., Eriksen, D., Bjørk, R., Nielsen, K.K., Barcza, A., Vieyra, H.A., Beek, N.V., Bez, H.N., Engelbrecht, K., Bahl, C.R.H. (2021) Novel design of a high efficiency multi-bed active magnetic regenerator heat pump, *Int. J. Refrigeration* **132**, 243-254.
- Masche, M., Liang, J., Dall'Olio, S., Engelbrecht, K., Bahl, C.R.H. (2021) Performance analysis of a high-efficiency multi-bed active magnetic regenerator device, *Appl. Therm. Engineer.* **199**, 117569-12.

Numerical model of the RES4BUILD multi-source vapour compression heat pump

ICT Software Digital solution

A detailed model of a water- and air-source heat pump (from multiple sources: solar, geothermal or air) was developed throughout the RES4BUILD project. It includes a pressure drop at the various stages of the cycle within the Engineering Equation Solver (EES) environment. Component sizing is also included in the model, making it possible to simulate in off-design operation. Its main parts (e.g., heat exchangers, compressor) are fully validated and can now be used for both design and simulation purposes.

The heat pump model could be used by heating, ventilation and air-conditioning (HVAC) manufacturing companies to better evaluate the performance of their products in real conditions and allows them to adjust their design. Moreover, it can assist engineering companies with the design of integrated systems including heat pumps. However, the main use will be further research.



Experience gained from the development and optimisation of the multi-source heat pump with cascade configuration will be useful for all applications where heat pumps are used, irrespective of the inclusion of a magnetocaloric heat pump.

The first complete version of the model is finalised and fully functional, although it will be continually improved, with more features added to increase the accuracy of its results and to allow for the use of different refrigerants. This final version of the model is complete and has been fully tested by the National Centre for Scientific Research Demokritos (NCSRD), including the use of two refrigerants. However, its main purpose will be the investigation of heat pump designs and its integration into other systems in further research, mostly remaining at research level.

Publications have been shared on Open Research Europe to build expertise within academia and institutes involved in energy systems modelling. The model will also be used in another research project by NCSR Demokritos.

Additional Information

- Dr. George Kosmadakis, NCSR Demokritos (gkosmad@ipta.demokritos.gr)

- Meramveliotakis, G., Kosmadakis, G., Karellas, S. (2021) Methods based on a semi-empirical model for simulating scroll compressors with HFC and HFO refrigerants. *Open Research Europe* **8**;1(148):148.
- Meramveliotakis, G., Kosmadakis, G., Karellas, S. (2022) Identifying the performance and losses of a scroll compressor with vapour injection and R1234ze (E). *Open Research Europe* **20**;2(49):49.

Use of low GWP refrigerant in a vapour compression heat pump

Scientific or Technological R&D Result

Fluorinated greenhouse gases (f-gases) are a group of chemicals containing fluorine. The EU f-gas regulation aims to reduce the environmental impact of fluorinated gases via regulation. The most common f-gases are hydrofluorocarbons (HFCs). Heat pumps and air conditioners use f-gases such as R134a, R410A and more recently R32 as refrigerants. The effect of each refrigerant on the environment is mainly determined by two coefficients: the GWP (global warming potential) and ODP (ozone depletion potential). All refrigerants with ODP higher than zero have already been banned and the current effort is to significantly reduce the GWP coefficient of the refrigerants. Refrigerants with a low global warming potential (GWP<150) significantly lower than R134a (GWP 1430), R410a (GWP 2088) and R32 (GWP 675) were tested in the RES4BUILD Vapour Compression heat pump.

R1234ze(E) did not prove to be very efficient for the expected boundary conditions (e.g., water temperature at the evaporator below 10-15°C) and was replaced by R454c (GWP=148), keeping most of the components of the heat pump the same. The tests that followed showed a high performance similar to R407c. This refrigerant (R454c) is newer than R1234ze(E) and has not been used before in heat pumps.

The operation of the refrigerant was evaluated within the RES4BUILD project regarding the following factors: Reliability (operating for one year at without malfunctions affected by the refrigerant); and Efficiency (comparison of the unit with the efficiency of other refrigerants).

The results can be used by heat pump and compressor manufacturers to further determine the potential of using new low GWP refrigerants in commercial applications.

Evaluating the use of a low GWP refrigerant for use on heat pump applications can be useful for all applications where heat pumps and air conditioners are used, as the new low GWP HFO refrigerants are expected to have a significant role in the future of air conditioning. Compressor manufacturers can add the new refrigerants to their compatibility list (especially R454c), and heat pump and air conditioner manufacturers can adopt it.

Additional Information

- Dr. Pantelis Bakalis, Psyctotherm (pbakalis@psyctotherm.gr)
- Pilou, M., Kosmadakis, G., Meramveliotakis, G., Krikas, A. (2022) Towards a 100% renewable energy share for heating and cooling in office buildings with solar and geothermal energy. *Solar Energy Advances* **1**;2:100020.
- Meramveliotakis, G., Kosmadakis, G., Pilou, M., Karellas, S. (2023) Testing a flexible configuration of a solar-assisted heat pump with PVT collectors for domestic hot water production. *Proceedings of Eurosun 2022* **TBC**

Borehole thermal energy storage controller

ICT Software Digital solution

A geothermal heat pump with vertical loops (Borehole Thermal Energy Storage or BTES) does not always use available energy in an optimal way. Usually there is no follow-up with the actual state of the BTES field, causing thermal depletion which results in insufficient heating during winter or insufficient cooling during summer. The BTES field can also be over-dimensioned for security of supply reasons, but compromising economic viability.

The BTES controller guarantees power (kW) of the BTES field and the annual energy production (MWh) for heating and cooling so that no extra installation investments are needed. The controller sets the required extraction or injection rate at any time, considering the heating and cooling energy that needs to be delivered later during the remaining heating/cooling season. This strategy enables the controller to actively anticipate, and thus avoid geothermal exhaustion. For bivalent systems, the optimal switching point for peak boilers or chillers is determined. The peak installation can be avoided or at least reduced.

The ultimate end user would be energy service companies (ESCOs) and building owners. Interim target users would include consultancy companies providing advice on BTES installations.

Currently the BTES controller is at TRL 3 – it has not yet been deployed. The technology needs to be validated and demonstrated in a relevant environment; however, project activities have shown that BTES installations are often over-dimensioned in such a way that they do not need smart control. As such there is no clear need for this type of solution right now. A concurrent market investigation has confirmed this. These results have provided a better understanding of how a BTES controller could work in practice and have also identified technical barriers that need to be overcome.

Additional Information

- Davy Geysen, VITO (davy.geysen@vito.be)

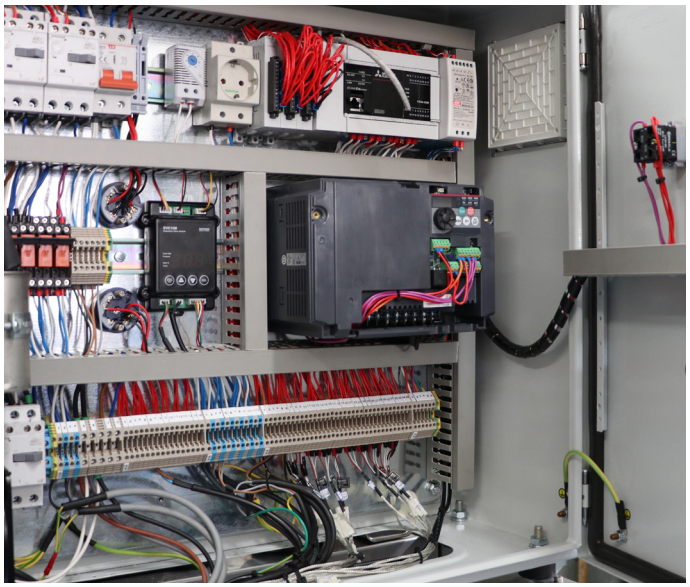
INTEGRATED MODELS AND SYSTEMS MANAGEMENT

Two pilot systems tested the integrated components, and project partners explored the challenges involved with implementing these systems into existing buildings.

Modified vapor compression heat pump and heat pump algorithm for integration with multi-source applications

Scientific or Technological R&D Result including ICT hardware/ICT Software Digital solution

Modification of the vapor compression heat pump to integrate efficiently with multiple sources (magnetic, air, geothermal and solar energy) is one of the main objectives of the RES4BUILD project. Due to multiple sources and the effective utilisation of the heat overproduction, the modifications aim to reach a higher COP (coefficient of performance) and EER (energy efficiency ratio) which describe the heating and cooling efficiency of heat pumps. The designed heat pump will have some innovative characteristics compared to current solutions, such as a two-stage compression with economiser for higher condensing temperature, two evaporators (one water source and one air source), and more sophisticated software.



The heat pump arrangement and supporting algorithm can be used by heat pump manufacturers to adapt their products to multi source applications. Additionally, it could be used by HVAC contractors who deal with multiple systems and can take advantage of geothermal and solar power in their applications to modify a commercial heat pump to a multi-source heat pump by applying their own algorithm for control and smooth operation. It may have additional potential applications for e.g., district heating.

Experience gained from the development and optimisation of the multi-source heat pump with cascade configuration will be useful for all applications where heat pumps are used, irrespective of whether a magnetocaloric heat pump is included or not.

A more sophisticated version of the software has been developed that includes the control of the valves of the whole system and modbus (network) communication with external systems (e.g., BMS or other hardware). This is currently undergoing testing.

Hardware design and PLC software will be restricted to project partners but additional routes to share knowledge and build expertise, as well as potential applications of the algorithm are being explored.

Additional Information

- Dr. Pantelis Bakalis, Psyctotherm (pbakalis@psyctotherm.gr)

Numerical model of an integrated energy system at the building level, focusing on the thermal network

ICT Software Digital solution

A numerical model of an integrated RES4BUILD system for buildings, considering the use of various components, was developed in Python. This model is based on thermal networks appropriately interconnecting the system parts. Adjustable control parameters are included, and its layout allows for the addition of more components and is easily connected with the energy networks (heating/cooling and electricity).

The system model can be used by engineering companies for the design of integrated systems, in particular where they include heat pumps and solar panels/collectors. Component sizing is a crucial parameter. It is also applicable to researchers of building simulations or other types of energy systems.

The model developed by NCSRD can be applied to integrated energy systems for buildings. Other possible applications concern the adaptation of this model for any other energy system where thermal energy flows are dominant and have a high level of complexity/unsteadiness. This model will reach TRL5 at the project end.

The complete version is finalised and fully functional. It is continually improved, with more features added to increase the accuracy of its results. The component models have been validated based on measurements of the two pilot systems in Denmark and Greece. Optimisation features will be added at a later date. However, the main purpose of the model will be the investigation of integrated energy systems in further research.

The results of the numerical model will be made available through publications, including the high-level description of the model and the processes considered.

Additional Information

- Dr. George Kosmadakis, NCSR Demokritos (gkosmad@ipta.demokritos.gr)

- Pilou, M., Kosmadakis, G., Meramveliotakis, G., Krikas, A. (2021) Renewable Energy Based Systems with Heat Pumps for Supplying Heating and Cooling in Residential Buildings. *In: The 34th International Conference on Efficiency, Cost, Optimization, Simulation and Environmental Impact of Energy Systems (ECOS2021)*, Taormina, Italy
- Pilou, M., Kosmadakis, G., Meramveliotakis, G., Krikas, A. (2022) Towards a 100% renewable energy share for heating and cooling in office buildings with solar and geothermal energy *Solar Energy Advances* **1**;2:100020

Widely applicable grey box models for thermal inertia of buildings

ICT Software Digital solution

Storage capacity is key to cope with the intermittent behaviour of renewable energy sources. In a built environment, batteries, electric water heaters and other types of storage tanks are typically used for increasing this storage capacity. However, due to the inherent capacity of buildings to store heat, e.g., thermal inertia of the building, they can be used as a flexible storage themselves.

Furthermore, this capacity to store heat and release it at a suitable time makes them ideal "flexible" loads. To use the flexibility in a planned and meaningful way, the way the building behaves needs to be characterised by modelling the thermal mass of the building with Resistance Capacity (RC) models. An RC network is built by connecting thermal resistances and capacitances as lumped parameters. These are analogues of electrical circuits and model thermal behaviour instead. The analogues for voltage, current, resistance and capacitance are given by temperature, heat flux, insulation, and the thermal mass respectively. Measured data or sample data from a white-box model is used to train the RC parameters of the models.

RC models for modelling the thermal behaviour of a building are already available. However, VITO have modelled them in a generic state-space representation approach to be able to easily use them in a framework for linear optimisation. On top of that, five types of RC models are implemented which can be used in an automated training approach in which the best fitted RC model is automatically selected based on the building's measurement data.

The models are trained using the open-source optimisation framework CasADi and can use both free open-source solvers as well as commercial solvers.

Currently, the RC models need to be validated in the lab and a real relevant environment. This validation will take place at a single-family house of the Belgian pilot and the Danish pilot system. The grey box models are expected to reach TRL 5-6 by the end of the project.

Additional Information

- Davy Geysen, VITO (davy.geysen@vito.be)

Optimization framework for simulation and real-time control of heating/cooling buildings

ICT Software Digital solution

Dimensioning a HVAC installation of a building including buffer tanks and optionally seasonal storage can be 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 optimisation framework developed in RES4BUILD uses an implementation applicable to both simulations and real-time control.

The optimisation framework can calculate an optimal operation plan for the heating/cooling system of a building, considering the comfort boundaries of the end-users. The calculated optimal plan is based on one of the following three objectives: self-consumption maximisation, energy cost minimisation and CO2 emission minimisation. However, it is easily extendible with other objectives.

To calculate the optimal plan, a Model Predictive Control (MPC) approach has been implemented, that makes use of simplified linear models of the complete system and building. Every type of linear model can be integrated if it is implemented according to the state-space representation of the physical system.

The main advantage of the framework is the generic configuration of different types of heating installations and different types of buildings. One can easily change the setup to be optimised by reconfiguring the descriptive JSON file. This means that no code must be changed to apply the optimization to a different building.

The optimisation framework can be used both for simulation and real-time control. When used in real-time control, it will be used in a receding horizon scenario in which it calculates a 24-hour control plan of which the first hours are used for control. After this, the new state of the system is read, a new optimisation is calculated, and the cycle is started again.

The framework uses the Python-embedded modelling language for convex optimisation problems, CVXPY, which can use both free open-source solvers as well as commercial solvers like GUROBI and CPLEX.

Currently, the optimisation framework needs to be validated in a lab and a real environment. The optimisation framework will be used both in the lab pilots of Greece and Denmark as well as in a real environment in the Belgium pilot. The goal is to have the framework at TRL 5-6 by the end of the project.

Additional Information

- Davy Geysen, VITO (davy.geysen@vito.be)

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CO-DESIGN AND ADVANCING TO MARKET

Case studies across Poland and the Netherlands informed and engaged stakeholders, while a full life-cycle impact assessment and market review brought the concepts closer to market.

Opportunities for multifamily buildings in the Polish market – heat pumps and photo-voltaics

Other Result

This output is based on BAPE's experience gathered when working on specific case studies in Poland within the RES4BUILD project. Information is lacking on IES options in multifamily buildings where the modernisation of heating and electricity installations is necessary and inevitable. These buildings, located outside the range of the district heating network (usually in rural areas), are often supplied with heat from local coal-fired boiler houses. In such cases, the implementation of Integrated Energy Systems (IES) should be considered.

PV installations are rapidly increasing in the Polish market. However, there is not yet an integrated approach to the modernisation of both the heat and electricity supply system. The following content has been summarised to fill this gap: Information on the RES4BUILD project; the European Green Deal and Renovation Wave; Energy efficient buildings; Heat pumps and PV technologies; IES; IES for multifamily buildings; and Environmental impact. This knowledge overview aims to support the decision making process around the upgrading of heating and electricity systems in Poland. It is particularly relevant for a number of end users where alternative solutions are being considered, taking IES into account.

The knowledge on IES would be useful to owners and users of multi-family buildings (private citizens, public owners like municipalities) as well as installers, suppliers of RES/IES in Poland.

The supporting knowledge exploring options and opportunities has been finalised in a brochure to share with end users. An updated version was published in January 2023. Further updates may be required as government policy changes. The development of the brochure is in collaboration with RES suppliers/project developers.

Additional Information

- Ludmiła Wach, BAPE (lwach@bape.com.pl)
- www.res4build.eu/results/tag/media

Framework for managing the implementation of integrated energy solutions for multi-stakeholder buildings

Other Result

This framework describes a diagnostic tool with basic technical, financial, and social/ organisational modalities for building stakeholders' groups to help them select how to prepare for and implement IES solutions (e.g., whether focussing on energy-neutral or near-zero emissions buildings) in their building.

The tool helps stakeholders to assess what steps they can perform themselves and/ or what external expertise is to be acquired for IES. This tool also guides stakeholders in engaging in co-creation processes for IES implementation in buildings.

The output, one generic modalities framework supported with a number of case specific examples, provides examples of good practice, a detailed process description, and planner guidance with tips on how this multi-stakeholder 'transition' process can be most effectively managed. It covers all the relevant phases before, during and after the renovation and links it clearly to the main technological, financial, and social challenges that these multi-stakeholder groups generally face.

The generic modalities framework provides support to different end-user groups with planning and organising their IES implementation process. It supports owners/ users/managers of buildings that have the ambition to perform an energy renovation of their owned or rented building(s).

It enables end-user groups to plan, organise, implement, and systematically monitor the complex decision-making process leading towards deep renovation of the building they own/use, including co-creation processes.

The relevant information on the modalities framework and the example applications are available in Deliverable 4.3. supported with Deliverable 4.2 (detailed case study reports). A training slide-deck may be made available for public real estate such as community centres, and for specific health care settings.

Additional Information

- Eise Spijker, JIN Climate & Sustainability (eise@jin.ngo)
- www.res4build.eu/results/tag/deliverables

Open system energy modelling platform

ICT Software Digital solution

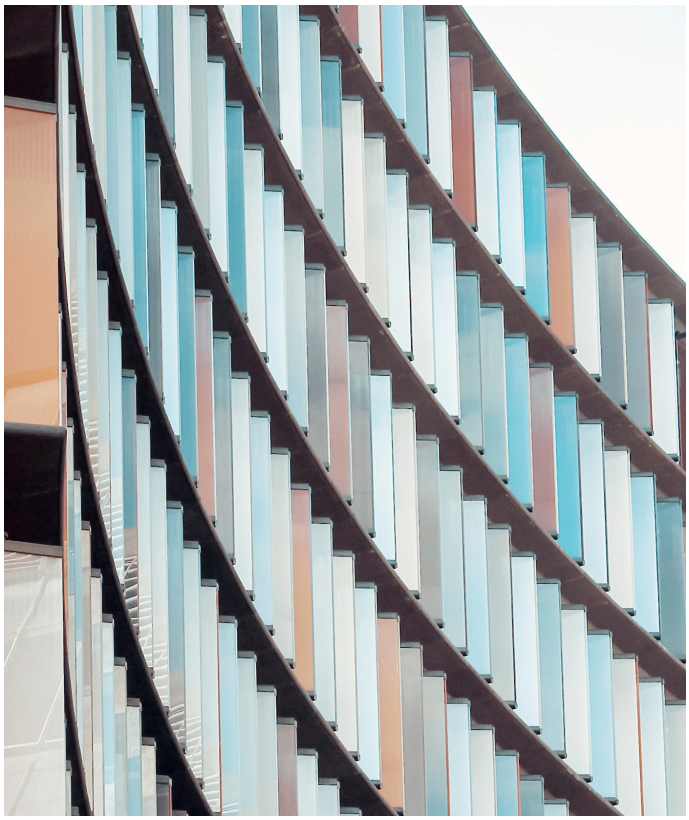
Early-stage design energy demand models are often required for estimating potential future building system size, cost and energy consumption, and options analysis. Creating these energy models can be time consuming and wasteful as projects change and design develops.

For RES4BUILD, the building typologies of the single-family home, multi-family residential buildings, commercial office building and public-school buildings were entered as geometries created in the Rhino software. The Rhino geometry was connected to the Grasshopper energy modelling script along with key inputs of the building fabric thermal performance to cost-optimal renovation level (sourced from country specific regulations) and ENTRANZE building characteristic inputs and outputs of the building thermal energy demand profile. This energy demand profile was then fed into the RES4BUILD WP3 system modelling software to simulate and size the required RES4BUILD system for the building which was later used in a GWP reduction impact assessment.

The open system energy modelling platform based in Grasshopper software and utilising existing representative building geometries and EU weather files would greatly reduce the time required to produce an estimate energy demand profile with only limited project inputs required to produce a usable output suitable for early-stage system design.

Alternatively, a database of selected energy models could be created with potential users accessing the most relevant energy demand profile to their projects based on limited inputs.

It can be used to speed up and create more flexible building designs enabling quicker early stage options analysis based on a representative demand profile, and enable



building system size and cost estimates for the project (e.g. comparison of a heat pump versus a boiler system for a given thermal energy profiles early in design. The information that the heat pump is more efficient, can fit in the space provided and has a lower lifetime cost leads to its inclusion in further designs).

The open system energy modelling platform or database would require further development to be user-friendly and to be at a large enough scale to be useful on projects. Access is restricted for now as it is likely to be developed and first used internally in Arup.

Additional Information

- John Smyth, Arup Consulting Engineers Cork (john.smyth@arup.com)

Life cycle assessment models for renewable energy technologies

Scientific or Technological R&D Result

The environmental impact of the innovative developed technologies as well as the complete RES4BUILD integrated renewable energy system was analysed using the method of life cycle assessment (LCA). The LCA methodology as described in EN ISO 14044 and ISO 14040 standards is used as basis for the environmental assessment, while the economic assessment specifications are based on ISO 15686-5 standard and DIN EN 16627 norm. This approach is the current best practice.

The LCA and LCE specifications are defined for the photovoltaic-thermal collector developed from MG Engineering, the magneto-caloric heat pump from the Technical University of Denmark, and the multi-source heat pump. The technologies are modelled in the environmental assessment software – GaBi using its professional database.

The life cycle phases of technology production, use and demolition were considered, and the following impact categories were assessed:

- Global Warming Potential
- Ozone Depletion Potential
- Photochemical Ozone Creation Potential
- Acidification Potential
- Eutrophication Potential
- Abiotic depletion potential for non-fossil resources
- Abiotic depletion potential for fossil resources
- Total use of renewable primary energy resources
- Total use of non-renewable primary energy resources

The LCA results can be used by the general public to benchmark and compare the performance of the technology against other technologies. The results are available in Deliverable 6.2.

Access to the model is currently restricted.

Additional Information

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Applied API for renewable energy technologies

ICT Software Digital solution

An interface for the exchange of life cycle analysis (LCA)/life cycle costing (LCC) information has been developed and integrated in the web software Generis®, to integrate LCA information in the digitalized automatized process of buildings' planning,

This is made possible through a dedicate web API where environmental and costs information can be exchanged between Generis® and the user, through 'manipulation' of an XML/XSD data structure.

A web API or otherwise an application programming interface, is a construct created for a web server or a web browser in programming languages to allow developers to create complex functionality more easily. It abstracts more complex code away from the user, providing easier syntax to use in its place.

A BoQ (Bill of Quantities) is extracted from the product provider and transferred to an XSD structure. The BoQ contains a list of all geometric constructions, elements and materials as well as their respective dimensions and quantities. The XSD-LCA module is integrated into the XSD structure. In this way the BoQ completes with information the LCA module of XSD structure, and the integrated XSD is then transferred to Generis from the web API. The LCA-XSD is developed together with a DGNB-XSD to enable the linking of life cycle data with the DGNB certification system for direct submission. In the LCA-DGNB-XSD, the information contains three LoDs, which correspond consistently to the modeling levels in Generis®.

The API for RES4BUILD builds on the general DGNB/GENERIS® XML structure, specifications of the modelled RES4BUILD technologies, and LCA/LCE specifications defined within the project. Data included in the interface is for example project and technology descriptions, LCA specifications and results.

This is an important step towards the integration of LCA into the design process of components and buildings. It offers an interface for the automated exchange of relevant data between different tools and models.

The API is currently being tested within the project but can be configured to different use cases (TRL7). By the end of the project it is expected to have a fully adaptable and easy to use interface.

Additional Information

- Rafael Horn, University of Stuttgart IABP (rafael.horn@iabp.uni-stuttgart.de)

PUBLICATIONS, DELIVERABLES, REPORTS AND HIGHLIGHTS

Additional outputs have been made available and accessible online.

Overview of other outputs

Publications

Over 15 academic articles have been published in open access. Various conference proceedings, theses and a book chapter have also been published throughout the project.

Articles

Additional popular science and industry relevant articles have been shared through the European Energy Innovation magazine as well as online channels such as BUILD UP and Climate Change Mitigation Portal.

- Smart Control for Buildings Powered by On-site Renewable Energy.
- Integrated Energy Solutions in the Built Environment: a necessity for the renovation wave?
- Carbon savings: detailed assessment of the carbon savings possible today by applying smart combinations of existing solutions in the European building stock.
- Novel H-pattern Design Improves Efficiency of PVT Solar Collectors.

Public Deliverables

Several reports have been made available on the project website:

- D2.4 Testing of the Integrated Heat Pump.
- D4.1 Good Practice of Integrated Energy Systems: on integrated energy systems in the built environment in Poland and the Netherlands.
- D4.2 Integrated Energy Systems Co-Design: results and lessons in the built environment in Poland and the Netherlands.
- D4.3 Modalities for Local Building Upgrading with Integrated Energy Solutions: upscaling the implementation of integrated energy solutions in the built environment.
- D6.1 Technology Factsheets: technological, environmental and economic key values.
- D7.1 Assessing the Project Impact: European building models and the benefits that can be achieved by the use of RES4BUILD systems.
- D7.2 Market Analysis and Business Models

Media

A number of other communication tools and materials were produced throughout the project, such as:

- Project News Updates
- Introductory Video
- Explainer Videos
- Final Video
- Summary Videos
- MCHP Video

Additional information:
The above resources can be found on the project website and the RES4BUILD Zenodo Community Page:

- www.res4build.eu/results
- www.zenodo.org/communities/res4build-project/

www.res4build.eu