# Strategic Energy Technology PLAN

*Temporary Working Group 5 on*

*Energy Efficiency Solutions for Buildings*

*Implementation Plan*

*Endorsed by the SET-Plan Steering Group*

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# INTRODUCTION

Energy efficiency in buildings (EEB) plays a strategic role in a large number of EU energy policies, in particular by limiting EU's **energy demand** and therefore improving its **energy security of supply**. It is also considered by IPCC experts as the single issue with the highest potential **impact on $CO_2$ emissions reduction** and **climate change** issues. In the building sector only one third of the energy savings potential arises from new buildings with a high energy performance. The refurbishment of existing buildings (e.g. building envelopes/ skins, heating and cooling systems, management and monitoring tools) shows a higher potential due to their larger number and the high energy demand of these houses. One of the most crucial roles in the energy savings potential in buildings is played by heating and cooling technologies as the demand for heating and cooling in the EU arises to more than half of the final energy. Fossil fuels and natural gas are still the main sources to meet the demand. Renewable technologies are only used marginally although their broad implementation would make a huge contribution to $CO_2$ reduction.

EEB is supported by an already solid EU regulatory framework - **EPBD; EED; Ecodesign…**- and is strongly connected to other subjects like the **circular economy** package and **efficient use of resources.**

Finally, EEB is also at the heart of **EU's Research, Development and Innovation** (RDI) policy with extensive contributions of **FP7** and **H2020** projects, in particular the EeB PPP. Moreover, European Regional Development Fund (**ERDF**) involvement in innovation and retrofitting thematics has also been growing and can be expected to remain a priority in many Member States for the next multiannual framework.

At all times, **citizens** are at the center of this energy efficiency approach. We spend indeed more than 90% of our time indoors. It is therefore not abusive in this case to talk of a new ecosystem, impacting our daily quality of life, for which we also seek to ensure each one's financial accessibility to the comfort of a clean and reliable energy.

In this context, the connection with Member States national strategies can find many natural paths for further developments and collaborations.

## SET-Plan Temporary Working Group 5

The SET-Plan coordinates low-carbon R&I activities in EU Member States as well as other participating countries (Iceland, Norway, Switzerland and Turkey). It was established to support the structuring of European and national research programmes in order to identify common priorities and trigger investments in those technologies.

The high potential of energy savings in buildings and the multiplicity of obstacles that need to be overcome in new buildings, existing building stock as well as cross cutting barriers legitimize the work of TWG 5 "Energy efficiency solutions for buildings". In the European Energy Union strategy one of the highest priorities in the energy sector of buildings and communities are highly efficient technologies for heating and cooling. Therefore, the SET-Plan TWG 5 was divided in two subgroups to address these aspects properly:

- New materials and technologies for energy efficiency solutions for buildings (5.1)
- Cross cutting heating and cooling technologies for buildings (5.2)

The Implementation Plan of TWG 5 sets out actions required to achieve the challenging targets for energy efficiency in buildings. It identifies ongoing projects and proposes new activities to address gaps where previous activities have left space for further optimization.

During the development of the Implementation Plan, all active members of TWG 5 agreed to keep working in parallel with both subgroups in order to achieve a more holistic approach. However, the following Implementation Plan shows two different sections of prioritized R&I activities organized by targets within each subgroup. All proposed R&I activities gathered the consensus of all active members.

The membership of TWG 5 is composed of Member States and non EU countries, industrial stakeholders, non-governmental organizations and research institutes. Meetings were held either in person or as online webinars. During the development of the Implementation Plan the TWG 5 experienced a high interest by stakeholders. Member States participation was limited though some of them were particularly active on a regular basis (see Table 1).

| **Member States and other countries** *(more regular participants)* | | **Stakeholders** |
|---|---|---|
| Austria | | Euroheat & Power |
| Belgium | | European Construction Technology Platform (ECTP) |
| Germany | | European Heat Pump Association |
| Italy | | European Association for the Promotion of Cogeneration, European Turbine Networks |
| Sweden | | European Geothermal Energy Council (EGEC) |
| Turkey | | European Platform of Universities in Energy Research and Education (EUA-EPUE) |
| France | | European Technology and Innovation Platform on Renewable Heating & Cooling (RHC) |
| | | SINTEF Energy Research<br>Steering Committee of the RHC Biomass panel |
| | | European Solar Thermal Industry Federation (ESTIF) |

Table 1: Active Participants in Temporary Working Group 5

The work of the **Temporary Working Group** is to be followed by an **Implementation Working Group** that meets on a regular basis that will allow several advantages:

- The progress of the outlined R&I activities can be monitored. If necessary, adaptations can be discussed and made during the implementation process.
- A regular exchange between the Member States can motivate those Member States, who did not participate in the development of the Implementation Plan so far, to join and exercise their responsibility to participate. Possible gaps or weak spots, caused by the low participation, can be adjusted.
- A permanent and long-term dialogue between the European Commission, SET-Plan countries and relevant stakeholder groups can be established. If required or needed the exchange with other groups of interest can be arranged for bilateral advantages.
- A regular exchange with already established instruments like the European Technology and Innovation Platforms (ETIPs), the European Energy Research Alliance (EERA), the

SET-Plan Information System (SETIS) as well as a coordinated collaboration with other Implementation Working Groups is absolutely necessary in order to avoid an unnecessary parallel structure.

In the implementation of the activities, a special focus will be placed on the articulation with European and national policies, the dissemination of the outputs of the projects in the construction and renovation sector, and on the follow-up to ensure that they meet the needs of the sector.

## Strategic issues

Advancing energy efficiency in buildings involves many challenges; from the development of new buildings to retrofitting solutions in the existing building stock; from improvement of single components to systems approaches for a whole building or even neighbourhoods; from data collection to management tools. The buildings sector is in direct exchange with the "user": it represents the most relevant interface to save energy and reduce emissions. In order to address the topic properly an **integrated approach** is necessary. This will be made possible by a combination of the solutions taken from the strategic issues mentioned here under.

The actions proposed will cover the following major drivers of the transformation of the buildings sector. Indeed, around the core of energy efficiency, the evolution is marked by the **digitalisation** of construction, the **industrialisation/standardization** of processes, the **sustainability** issue by responding to circular economy principles, and the innovation and optimisation around **building systems for heating and cooling** and their integration into the building.

- **Digitalisation of construction:**

With the development in recent years of **BIM (Building Information Modelling)** from conception to building's end of life, the construction sector is experiencing a fundamental revolution. BIM's implication in energy issues is considerable not only for the building's management during its operating life, but also to optimize the design and construction phase as well as in the planning of deconstruction.

Nevertheless, this technology is mainly used for new construction projects which remain limited in number, if we compare them to the global building stock. Given the strategic importance of building renovation to reach energy targets, a useful approach could consist of identifying and fine tuning technologies that would allow to **digitalize existing buildings**. For example, through developing evolutions of techniques for **drone scanning** for external envelope and **laser 3D systems** for indoor modelling, it should be possible to execute both physical and infra-red thermal modelling of existing buildings, allowing the implementation of BIM for energy planning of the retrofitting works. One other key aspect of this RDI need is **affordability** to ensure wider use and easy dissemination of these technologies. During operating life, the BIM model of the building, combined with the use of **connected objects** will guarantee an optimal energy management.

Buildings are being more and more equipped with **smart metering systems** and generate an immense amount of **data**. To tackle this big data issue and develop its concrete exploitation, one extremely promising technology is the so called **blockchain technology.** It allows the secure and anonymous transfer and exploitation of various sorts of data. The broader implementation of the ambitious technology of blockchain will lead to a reorganization and large-scale modifications in the energy system that will be accelerated by individual players. The use of blockchain technology for smart contracts will revolutionize energy trading and it allows a new management of energy data in the building regarding data collection, storage and elaboration, data ownership, and protocol standardization.

More generally concerning data, it will be essential to also consider using **existing data platforms,** like the "EC Smart city information system" (SCIS)[1] for example and most of all avoid double-structures for the same data collection.

To ensure quality of the data, it is also crucial to concentrate on **reducing the difference between predicted and measured energy performance**, a crucial approach to optimize the successful impact of the digitalisation of the construction process.

- **Industrialisation and Standardization**

Several of the targets addressed in the Implementation Plan strive for a **cost reduction** in different fields. Investment cost reduction can be accomplished by standardization, repetition and ultimately economy of scales in the production, as well as optimal design choices.

New advances in **prefabrication** techniques and **modular construction** allow considerable gains in energy efficiency (and time) for the production and installation of construction materials. Besides, these also open new possibilities for **mass customization** of the modules enabling a better response to architectural demands.

Regarding **standardization**, it can be applied to formats, interfaces and performance indicator. Multinational activities can also help to strengthen the use of common European standards.

Therefore, not only the target of research and innovation activities is relevant, equally important is the involvement of the "right" stakeholders in research projects. Along the chain from basic research to commercialization it is of growing importance to involve industrial stakeholders. Finally, the constant transfer of results from R&I projects to policymakers, industry, relevant stakeholder groups and practice is important to accelerate the acceptance and market uptake of innovations.

- **Sustainability: circular economy and new materials**

Beyond energy performance, buildings and their construction materials are now under the pressure of much higher quality standards. The construction sector is under permanent scrutiny concerning its **waste** management. Its already ongoing efforts to reduce these wastes according to – or going beyond – regulation need to guarantee **high rate of reusability / recyclability** of the **raw materials** and other products. This is the principle of the **circular economy.** This new approach can have a strong positive impact on the life cycle energy consumption and therefore massively contribute to the energy transition. To

[1] https://smartcities-infosystem.eu/

tackle this new challenge, a variety of solutions has been explored and deserves further effort. **Biomaterials** are by essence highly recyclable or reusable, and most of them are biodegradable (agricultural by-products; wood; corrugated paper; textiles…). RDI has also made dramatic progress even on **concrete** which is rapidly evolving into a reusable/ recyclable material. More sophisticated materials like **mineral foams**, **phase change materials** or **silicate aerogels** for specific needs illustrate the large variety of solutions that can be further developed.

There is also a growing demand for an approach that takes into consideration the whole life cycle of both energy and carbon, as illustrated by the development of Level(s)[2], the voluntary common EU approach to the assessment of environmental performance in the built environment.

One step related to materials and energy worth being considered is **embodied energy**, i.e. the energy used to produce a given material. To consider this characteristic is also contributing to reduction of energy demand and $CO_2$ emissions. One example is **unfired clay**.

As a last point on construction materials have also evolved into energy producing materials, like **Building Integrated Photovoltaics (BIPV).** Although generally tackled in PV related chapters, it is important to recall that it is a façade or roof element with PV capacity and therefore has to be compared to non PV equivalents, rather than compared to a full fledge PV panel, which will always have a higher cell density. A follow up will be made with the TWG on PV.

**The Heating and Cooling Systems** provide a dramatic potential for reduction of the energy consumption at building level. Relatively new technologies for (renewable) energy conversion to heat, like the heat pump and micro-cogeneration still have a high innovation potential and need guided actions for further market introduction and uptake. Distribution of heat and cold on a larger scale is enabled by district heating and cooling systems that have economic benefits over distributed systems in a large part of the built environment, especially in high-density areas and in districts with a large share of historical buildings. Short term and long term thermal energy storage technologies will help to increase the share of renewables in the final energy demand and to increase the efficiency of heating and cooling systems. There is still a big need for further materials, component and system development in thermal energy storage in order to find the best solutions to the large number of different applications. The pressure on improving and bringing to the market heating and cooling systems is even greater in particular due to the accepted forecast of a **massive increase in cooling demand** in the years to come. Innovation is therefore strategic for all the systems responding to the different needs.

The measurement of the performance shall occur at all times in the life cycle of a building that is to say during its design, its construction, throughout the duration of its use. In this regard, during the exploitation phase, the occupation has an impact on energy performance and should also be considered.

[2] http://ec.europa.eu/environment/eussd/buildings.htm

## INNOVATION TARGETS

In order to promote highly efficient material and technological solutions to increase EEB, the European Commission, representatives from the SET-Plan Steering Group (EU Member States, Iceland, Norway, Turkey, and Switzerland) and representatives from stakeholders defined four strategic Research and Innovation Targets in both subgroups. The research and innovation activities to achieve those targets by 2025 can further underpin the implementation of the EU policy framework, respond to market's needs and accelerate the transformation of our building stock, by focusing on the existing technological barriers as well as non-technological elements.

### Action 5.1 NEW MATERIALS AND TECHNOLOGIES FOR ENERGY EFFICIENCY SOLUTIONS FOR BUILDINGS

| | |
|---|---|
| Target 5.1-T1 | Reduce on average the primary energy of buildings by 60% compared to their costs in 2015, while reducing total cost of ownership and limiting the payback time to 10 years. |
| Target 5.1-T2 | Develop and demonstrate market ready solutions to reduce the construction and maintenance costs of Nearly Zero Energy Buildings (NZEB) or positive energy buildings by at least 10% compared to their costs in 2015 with a view to reach a cost reduction of 15%. |
| Target 5.1-T3 | Develop and demonstrate market ready solutions to reduce the average duration of energy-related construction works by more than 20% for renovation and for new buildings compared to current national standard practices. |
| Target 5.1-T4 | Develop and demonstrate market ready solutions to reduce the difference between the predicted and the measured energy performance to maximum 15% after the commissioning period with the ambition to reach 10%. |

Table 2: Agreed specific targets Action 5.1

Target 5.1-T1 was chosen because renovations are too often lacking a holistic approach (at the building level, but also at neighborhood and city level, in order to optimize urban planning). They include insufficient energy efficiency measures and they are sometimes facing comfort, operation and moisture issues. In addition, the pay-back time for ambitious energy renovations is considered too long by most building owners. Target 5.1-T1 was assessed as the most challenging Innovation Target due to the fact that it is only achievable by deep retrofitting of existing buildings or the construction of brand new buildings. In order to achieve the target demonstration projects are required that take a bioclimatic design, the use of ICT, different materials and prefabricated modules into account. Also the integration of all systems and various energy supplies is needed. The payback time of 10 years will still be difficult to achieve.

In many countries Nearly Zero-Energy Buildings (NZEB) are relatively expensive to construct and sometimes maintain, compared to buildings that only comply with standard building codes and regulations (with estimated average additional costs being in the order of 10%). Innovation Target 5.1-T2 was still considered as a minimum target that can be overachieved with the correct activities. The development of efficient prototypes and functional business models can be reached for timber as well as for brick buildings. Collaboration with Action 3.2 "Nearly Zero Energy Districts" should be favoured.

Delayed and lengthy construction works tend to increase costs and disturbance for occupants in case of refurbishment. Construction processes are currently carried out alongside largely different patterns, involving a large number of players, mainly SMEs, which are not sufficiently interconnected along the different stages of the construction processes. Digital related solutions and implementing digitalization of construction processes is seen as a key aspect in order to achieve Innovation Target 5.1-T3 (e.g. delivery of materials: the right time, the right amount and the right place can be coordinated via digitalization processes). The skills and the training of workers as well as technologies that ease work should be considered in relevant R&I activities.

The gap between the predicted and the measured energy performance creates uncertainties for investors and hampers future investments. Model buildings as living labs are considered a useful research format to reach Innovation Target 5.1-T4. Depending on the complexity of the buildings fine-tuning periods for monitoring systems should be taken into account. Digitalization and ICT play also a key role in order to establish smart buildings. R&I activities that focus on this target should also consider the consumer and the consumers behavior. Actions supporting the skills of all professionals involved in the building value chain are equally important to reduce the performance gap.

Additional avenues for work are the performance of building envelopes and the improvement of the product performances (e.g. decrease of thermal bridges, improvement of windows performances).

### Action 5.2 CROSS CUTTING HEATING AND COOLING TECHNOLOGIES FOR BUILDINGS

| | |
|---|---|
| Target 5.2-T1 | Heat Pump Systems: Cost reduction for small and large size heat pumps by 50% (compared to 2015 market price); Development of prefabricated, fully-integrated 'plug in and play' hybrid/multisource heat pump systems and integrated compact heating/cooling plants based on modular heat pumps. |
| Target 5.2-T2 | District heating and cooling: Increase amount of renewable heat by 25% (compared to 2015), cost effectively and without decreasing the service provided to consumer; Decrease of the DHC substations reference costs for residential buildings by 20% (compared to 2015 prices). |
| Target 5.2-T3 | Micro CHP/CCHP: Cost reduction for equipment and installation by 50% (compared to 2015 market price); Increase of the energy efficiency of Micro CHP/CCHP by 20% (compared to 2015 levels) by increasing operational electrical efficiency and maintaining thermal efficiency. |
| Target 5.2-T4 | Thermal Energy Storage: Improve the performance of above ground and underground energy storages (Energy efficiency, system lifetime, O&M) by 25% (compared to 2015 levels): Increase of 200% of storage density at the system level (including pumps, valves, pipes, short term buffer) from the current state of the art 60 kWh/m³. |

Table 3: Agreed specific targets Action 5.2

To complement this table with a view to future work, one can mention energy recovery technologies that are promising leads to the circular economy of energy.

At present, heating and cooling of buildings is predominantly done by direct burning of fossil fuels and thus offers a very large opportunity to decarbonise the energy demand of the built environment.

The future possibilities for direct use of renewables for heating and cooling of buildings are solar thermal and ambient heat, the latter through the use of heat pumps. Indirect sources for this are renewable electricity for driving heat pumps and green gas or other waste streams for micro cogeneration of heat and power or micro cogeneration of cold, heat and power. As especially the heating demand for space heating has a large variation over the year, but also over shorter periods, thermal storage is a very important, enabling technology for a fully renewably heated built environment.

Due to their specific importance for renewable heating and cooling of buildings, the fields of Heat Pumps, District Heating and Cooling, Micro CHP/CCHP and Thermal Energy Storage have been identified as Targets by the TWG 5.2.

On Target 1 (Heat Pumps), 6 Activity Fiches were drawn and finally combined, proposing work on development of a heat pump kit for replacing existing boilers, development of high temperature heat pumps for industrial processes and District Heating and Cooling, development of intelligently controlled heat pumps that deliver extra services to the grid, development of an interoperable, flexible heat pump, development of absorption technologies (thermally driven cooling systems) to increase the utilisation of district heat, waste heat and renewable heat, and the development of gas sorption heat pump systems for different applications and climatic areas. The pursued cost reduction is considered a challenge, especially for large scale heat-pump systems, since they are rare and installation is quite costly. In order to achieve this target, standardization and replication are the key aspects that should be addressed in R&I activities. Use of Key Performance Indicators (KPI) for heat pump systems to increase the comparability between Member States is also favourable. While basic research is not seen as a priority in this target the system approach should be addressed in demonstration projects.

On Target 2 (District Heating and Cooling), 3 Activity Fiches were drawn and finally combined: on the development of multi-source district heating, on the development of higher temperature District Cooling systems, and on the optimisation of building heating systems leading to a minimisation of the district heating temperature levels. In order to keep DHC competitive an increase to 100% renewable heat should be carried out. The proposed activities on Target 2 have strong interfacing with the proposed activities in the SET Plan TWG4 “Increase the resiliency and security of the energy system”, grouped under the Flagship 2 (Develop integrated local and regional energy systems).

For Target 3 (Micro CHP/CCHP), 2 activity fiches were prepared and finally combined: on the development of hybrid micro-CHP for residential and commercial buildings, and on the development of energy efficient micro CHP/CCHP technologies for single family houses. R&I activities that show a higher TRL (>6) should involve municipalities and or waste management as partners.

For target 4, one activity has been defined for the research on and development of compact thermal energy storage technologies for individual buildings. Thermal Energy storages are addressed in most ongoing projects concerning material and component improvements as well as system integration. As the challenges are strong in this field, an intensification of the

R&D effort on international level is required. European collaboration and exchange of results is favourable.

## NON-TECHNOLOGICAL ISSUES AND OTHER CONSIDERATIONS

Particular attention has to be given to non-technological issues. These are key factors to achieve reduction of EU's energy demand, and are as important as technological issues. The success of RDI on Energy Efficiency in Buildings is deeply connected to the following issues many of which should be further developed and remain also valid for other Temporary Working Groups.

- **Education and Training of all actors:** from the conception to the deconstruction, with a particular focus on operating life (users, building manager, technicians…)

While new technologies and materials often target the reduction of energy consumption and $CO_2$ emissions, a system consisting of energy efficient parts is not necessarily energy efficient. During the process of construction, commissioning and operation all individual components must be coordinated with each other. Also the correct management and use of the building are crucial to fully develop the energy efficiency effects. Therefore non-technological aspects such as the training of buildings sector workers, skills development, technologies to ease work as well as the consideration of consumer's behavior and the involvement of consumers are highly important. In new research and innovation activities in an operational environment those aspect have to be taken into account.

- **Architecture**

Functionality but also aesthetics are unavoidable criteria in the design and construction process and have therefore to be married in the best possible way with the energy focus. *Bioclimatic architecture* aims at optimizing natural lighting and ventilation and can play a strategic role in in the energy equation of the building. *Biomimicry* is on its side a particular principle that aims at "copying and adapting solutions" found in nature.

- **Urban planning**

The building may also benefit or suffer from its immediate surrounding: neighbouring buildings (shading, drafts…) or presence of trees or water surfaces (shading, moisture, cooling…) can contribute to or mitigate the urban heat island effect. If planned adequately, these elements can also contribute to optimizing the energy management of the building by moderating the surrounding microclimate.

- **Synergy with Transport**

Production, consumption and storage of renewable energies on/in the building must be considered in integration with electromobility infrastructure.

Additional topics such as the analysis of decision-making process, the development of financing and legal tools, should also be investigated.

TWG 5 proved to be extremely creative on proposed actions. Only a selection of those with the strongest support are now presented in the Implementation Plan but there is a high quality reserve available for eventual future opportunities.

# SUMMARY

Around 40% of the final energy consumption in Europe is due to the building sector. This shows the great potential for energy savings and the enormous importance of this sector for $CO_2$ reduction and climate protection.

The SET-Plan TWG 5 on “Energy Efficiency Solutions for Buildings” with the subgroups 5.1 “New materials and technologies for energy efficiency solutions for buildings” and 5.2 “Cross cutting heating and cooling technologies for buildings” developed a detailed implementation plan for the support of 8 defined targets by 2025 agreed by representatives of the European Commission services, representatives of the EU Member States, Iceland, Norway, Turkey and Switzerland (the SET-Plan Steering Group), and representatives of stakeholders, outlined in two Declarations of Intent of 2016.

Proposals have been developed by a group of expert stakeholders from industry, research and the member states. Issues of a technological, socio-economic, and regulatory nature relevant in achieving the targets have been identified. In the course of the work process, ongoing national and EU-Projects under each R&I Activity have been listed and new actions have been deduced from the proposals. Finally, declaration of interest and indicated financial contributions of the member states, the private sector, research organizations, and universities have been gathered.

The Implementation Plan outlines 8 key Research and Innovation (R&I) Activities, required to achieve the ambitious targets for the building sector:

- New materials for buildings
- Prefabricated active modules for façades and roofs or Key Enabling Technologies for active building skins
- Digital planning and operational optimization
- Living labs - Energy technologies and solutions for decarbonized European quarters and Cities
- Cost-efficient, intelligent, flexible heat pumps (also thermally driven) and heat pumps for high temperatures
- Multi-source District Heating integrating renewable and recovered heat sources, higher temperature District Cooling and optimization of building heating system, to minimize the temperature levels in district heating networks
- Cost reduction and increase in efficiency of micro CHP/CCHP
- Compact thermal energy storage materials, components and systems.

All targets of Action 5.1 and 5.2 are properly addressed with Activities. 6 countries have expressed interest in supporting the proposed Activities and partly committed financial contribution: Austria, Belgium, France, Germany, Italy, and Sweden. The Activities proposed in the Implementation Plan are of strategic importance but can also be supplemented by more Activities during the implementation phase. Other Member States are also invited to contribute in the further work process.

TWG 5 considers it important to collaborate with the other SET-Plan Working Groups as strong synergies can be developed, in particular on renewable energies and Smart Cities issues.

# ANNEX

## Activities Action 5.1

### R&I Activity 5.1-1: New materials for buildings


**Strategic Energy Technology Plan**
Action 5.1
New materials and technologies for energy efficiency solutions for buildings

**Implementation Plan – Activity Fiche**

**Innovation Target: 1**
Reduce on average the primary energy of buildings by 60% while reducing total cost of ownership and limiting the payback time to 10 years
**Innovation Target: 2**
Develop and demonstrate market ready solutions to reduce the construction and maintenance costs of Nearly Zero Energy Buildings (NZEB) or positive energy buildings by at least 10% compared to their costs in 2015 with a view to reach a cost reduction of 15%

**Title:** New materials for buildings

**Individual building** ☒ **Neighbourhood/ District** ☐ **Others** ☐

**Activity number**: AF 5.1-1

**Description:**
Selection and development of materials and technologies for modern building construction and refurbishment have to satisfy many requirements nowadays. In addition to energy performance, technical and handling aspects, environmental impact and sustainability have become important aspects. While a continuous development of materials with respect to energy efficient buildings has led to new approaches like e.g. vacuum isolation panels (VIPs) structured insulation panels (SIP), smart windows or polymer foils with functional coating, life cycle assessment (LCA) method has put materials and technologies used for building construction into a larger context considering the energy used in each life cycle phase from raw material to end of life. Therefore, beyond energy performance, much higher quality standards are now requested for buildings and their construction materials. The construction sector is under permanent scrutiny concerning its waste management. Its already ongoing effort to reduce these wastes according to or beyond existing regulation needs to guarantee a high rate of reusability / recyclability of the raw materials and other products. This is the principle of circular economy which can have a strong positive impact on the global energy consumption and therefore massively contribute to the energy transition. Biomaterials are by essence highly recyclable or reusable, and if cycle is broken, most of all biomaterials are biodegradable (agricultural by-products; wood; corrugated paper; textiles, most biopolymers…). Even traditional building materials like bricks and concrete have the potential to evolve into a reusable/ recyclable material with additional functionality and reduced CO2 footprint. Promising examples with respect to low embedded energy are for example unfired clay and engineered wood. More sophisticated materials like mineral foams, phase change materials or silicate aerogels for specific needs illustrate the large variety of solutions that can be further developed.

**Impact:**
Reduced $CO_2$ emission, energy consumption and construction/maintenance costs by the development and application of innovative materials and technologies for the construction/refurbishment of buildings.

**Expected deliverables:**
Development and demonstration of thermal insulating construction system for building walls with improved energy performance and cost reduction across Europe representing various technical solutions and material compositions.
Projects in this activity should contribute to the following topics:

- Innovative materials and technical solutions applicable for the construction of new buildings and/or refurbishment of existing buildings
- Innovative insulating construction systems with thermal performance (with respect to heating and cooling requirements) equal or better than contemporary state of the art level.
- Compliance with existing structural, thermal, seismic and fire safety regulations
- Innovative thermal insulating construction system for building walls without any materials coming from fossil sources (petroleum, coke).
- The majority of the used material (at least 80%) is recycled at the end of life of the building.
- The used materials and technologies for construction support an easy and sustainable recycling process
- Reduced material, construction and maintenance costs thanks to low embedded energy, prefabrication, standardization and recycling.
- High potential for an implementation at European level.

**Monitoring Mechanism:**
Annual report summarizing the progress

**TRL:** 2-9

**Total budget required:** 40-60 m€ /5 years

**Timeline:** First projects in 2019, impact goals for 2023

| **Parties / Partners**<br>(countries / stakeholders / EU) | **Implementation financing / funding instruments** | **Indicative financing contribution** |
|---|---|---|
| Italy<br>Industrial Partners<br>Engineers, Architects<br>Universities and Research Institutions | Ministry of Economic Development (MISE), Ministry of Education, University, and Research (MIUR), funding from Regions | substantial financing contribution is intended but cannot be specified at present |
| Germany | National funding (Federal Ministry of Economics and Energy) and industry resources | 20 m€/5 years |
| Sweden | Swedish Energy Agency, Swedish Research Council FORMAS, Industry resources | Sweden is interested in the activity, but currently cannot provide an indicative level of financial contribution. |
| European Research Institutes / Universities | Ministry of Economic Development Europe<br>Horizon 2020 | |
| European Construction Technology Platform (ETCP), Energy Efficient Building Association (EEBA) | | |

**Non-technological aspects:** education workers

**Global issues addressed:** life cicle approach

| Ongoing R&I Activities (Flagship activities or not): relevant to this new activity proposal | | | | |
|---|---|---|---|---|
| **Name** | **Description** | **Timeline** | **Location/Party** | **Budget** |
| *COOL IT* | Development of cool concrete for precast/ready mix building elements (façade/roof) and pavements with increased solar reflectance to mitigate directly urban heat islands phenomenon and indirectly improve energy saving of building, mainly in summer season/warm climates. The energy saving should be evaluated by means of computational analysis tools.<br>Prototype building realization, by cool concrete (facades, roofs, pavements) with improved solar reflectance performances, targeting the energy saving of 3 – 5%. | 12/2017-11/2020 | Italy | 1.2 m€ |
| *RoKoDaMi*<br>*Project ID: 03EGB0008AB* | The goal of this Project is the demonstration of a newly developed insulation board for the insulation of pitched roofs on top of the rafters based on the renewable resource typha (cattail). Additionally during this project an optimisation of the product shall be performed and open questions concerning technical issues as well as quality aspects should be answered. | 10/2017-12/2019 | Germany: Fraunhofer IBP, SAINT-GOBAIN ISOVER G+H | 1.4 m€ |
| *HFV*<br>*Project ID: 03ET1324A-F* | Highly insulating evacuated façade elements: Goal of the project is the development of highly insulating evacuated elements for facade and refrigeration applications. In contrast to established Vacuum Insulation Panels (VIP) with high barrier laminates, the new elements use glass, metal, or combinations thereof as gastight front and back cover. The cover materials glass and metal are much less permeable against gases than the high barrier laminates which allows the use of cheaper core materials if a lower gas pressure inside the elements can be realized. Such elements would have the following advantages: lower production costs with increased market potential, better insulation values, smaller system thicknesses, easier production processes, and in case of the partly transparent system view-through and use of solar energy gains. | 06/2016-05/2019 | Germany: ZAE, BSH, Energy Glas, Kömmerling, Mosy, Hölscher | 3 m€ |
| *KOMPAP*<br>*Project ID: 03ET1414ABCE* | Development of sandwich structures of paper based and mineral layers as sustainable system solutions for energy efficient buildings and insulating systems:<br>Objective of the project is the development of system solutions of paper based wall structures with mineral layers for buildings. Paper based structures such as foams or honeycomb cores contribute to thermal insulations as well as to the stability of the structure. Mineral components take over protective functions against weather impacts and contribute to the stability of the structure. These structures should have higher stability | 03/2017-02/2020 | Germany: TU Darmstadt, PTS, Glatfelter, Fraunhofer LBF | 1.7 m€ |

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| | in combination than conventional solutions. Additionally, for the thermal insulation sustainable raw materials are used. The required fundamentals for the development are largely available in the areas of civil engineering paper technology, light weight construction and chemistry. Well known solutions from other areas have to be adopted and optimized for the present questions. This happens widely on an experimental basis, supported by modelling and simulations. In the frame of the project demonstrators will be developed at least in the pilot plant scale to illustrate the solutions of the essential crucial questions and the applicability of the new structures. | | | |
| *TaLed*<br>*Project ID: 03ET1330A-G* | Energy and cost efficient, façade integrated Day and LED-lighting based on micro-optical components: The application of micro-structured optical components for the efficient use of daylight and electric lighting is intended to improve the energy performance, life cycle balances, and the quality of the interior environment in buildings. This improvement will be based on two innovative structures which can be manufactured at low price, and the functions of which can be combined. The first of these concerns light redirecting structures, which are applied to both surfaces of transparent backing layers and have been optimized to guide daylight deeply into building sections far removed from the façade without causing disturbance due to unwanted glare effects. The second innovation concerns light emitting structures that are attached to the surfaces of transparent carriers, which selectively emit laterally incident LED light on one side only. Viewed from above, the element will remain transparent. The application of these structures in/onto thin carrier layers takes account of future environmental, economic, and energy requirements with regard to the minimum use of materials, the optical efficiency, the option of mass production, and the good suitability for further processing in glass composites, luminaires or a combination of both (luminous glazing). | 03/2016-02/2019 | Germany:<br>R.I.F. e.V.,<br>Durlum,<br>green building,<br>Fraunhofer IBP,<br>Temicon,<br>Jungbecker,<br>Saint Gobain Sekurit | 2.1 m€ |
| *Follow-e2*<br>*Project ID: 03ET1468A-E* | Subject of the project is the refinement of transparent polymer films for use in architectural applications by vacuum deposition processes and rotogravure coating. Energy efficiency, sun protection and thermal comfort of film-based buildings will be improved. The project examines the manufacturing process from processing of the coated ETFE films to the actual cushions and up to the final installation on site, focusses on the development of coating systems according | 03/2017-08/2019 | Germany:<br>ROWO Coating,<br>Fraunhofer ISE,<br>Dunmore Europe,<br>2Construct,<br>HfT Stuttgart | 1.4 m€ |

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| | to these requirements and on the presentation of a repair system. Furthermore, a product portfolio for different building types, user scenarios and climate zones will be developed. | | | |
| *Insulating strong nanocomposite foams made with controlled bonding* | The purpose of the project is to explore and develop novel, thermally insulating materials based on nanocomposites of renewable and widely abundant raw materials such as cellulose, clay and carbon. The proposal builds on the applicants' expertise in colloidal processing and directed assembly and recent discovery of how mechanically strong, flame-retardant and light-weight nanocellulose-graphene oxide-based foams, that exhibit excellent thermal insulation, can be obtained by ice-templated assembly. The aim is to develop a better understanding of the directed assembly process and the structure-property relations of superinsulating nanocomposite foams. It will further be investigated how the thermal insulation and mechanical properties depends on the composition, size and shape of the organic and inorganic components, and the structural features of the foams themselves, i.e. the cellular structure and the microstructure of the cell walls. Attempts will also be made to scale up the process and produce demonstrators for testing. | 2015-2018 | SE: Stockholm University, | 0.36 m€ |
| *Evaluation and optimization of a heat storage with phase change materials for better energy management in buildings - field studies, modeling and laboratory experiments* | The application relates to the evaluation of an innovative thermal storage for heating of hot water, with phase change materials (PCM) as the heat carrier. This PCM storage is constructed of plastic rods filled with aqueous salt solutions, embedded in a well-insulated tank. The rods (Swedish invention) are tightly sealed, easily manageable and stackable, so that the heat storage capacity can be easily changed. Preliminary tests have shown that PCM storage is more efficient at storing heat at uneven production (solar, waste heat) than traditional water-based heat storage, and can reduce heating requirements in buildings. A tank with 1000 rods (350 kWh) is to be evaluated in use. Field studies will be complemented by numerical modeling and lab experiments. The overall project objective is to develop design tools, which are currently lacking, for similar PCM storage. The experimental facility can become an objective demonstration and pilot project. | 2015-2018 | SE: Chalmers University | 0.36 m€ |

## R&I Activity 5.1-2: Prefabricated active modules for façades and roofs or Key Enabling Technologies for active building skins


**Strategic Energy Technology Plan**
Action 5.1
New materials and technologies for energy efficiency solutions for buildings

### Implementation Plan – Activity Fiche

**Innovation Target: 2**
Develop and demonstrate market ready solutions to reduce the construction and maintenance costs of Nearly Zero Energy Buildings (NZEB) or positive energy buildings by at least 10% compared to their costs in 2015 with a view to reach a cost reduction of 15%
**Innovation Target: 3**
Develop and demonstrate market ready solutions to reduce the average duration of energy-related construction works by more than 20% for renovation and for new buildings compared to current national standard practices

**Title:** Prefabricated active modules for façades and roofs or Key Enabling Technologies for active building skins

**Individual building** ☒ **Neighbourhood/ District** ☐ **Others** ☐

**Activity number**: AF 5.1-2

**Description:**
Energy retrofit of buildings is mainly entrusted to the façade performance improvement in terms of thermal transmittance. These interventions, often are particularly cumbersome (considerable increase in the thickness of the perimeter walls), expensive and do not exploit all the potential offered by existing technologies. Especially in Mediterranean climate, the cost of a deep renovation is often not justified with respect the energy saving obtained.
Ventilated façades offer a great opportunity to host in a modular way active, passive and storage technologies in order to decarbonize the building sector.
Proposals should focus on the development and demonstration of standardized panels for ventilated façades or roofs combining PV, solar thermal, insulation, PCM and batteries. The modules have to be developed in order to cover the needs of different markets and different climate zones.
Modularity and standardization should be addressed in order to minimize costs and increase the supply on the market.
Prefabricated façades are well suited for refurbishment tasks because they also can integrate pipes for installation equipment and keep construction times low.

LCC and LCA might support the prototypes development. A complement with smart windows is also possible.
The proposals should follow the general objective of innovating the building process in terms of environmental sustainability, incorporating the advantages associated with the extensive use of light and/or high energy performance recyclable materials with innovative systems for renewable energy generation, storage and energy management.

**Impact:**
Projects in this topic will contribute to reduce the time and cost needed to build new façades for residential and non-residential buildings. The integration of PV, solar thermal, energy storages, power electronics, insulations, PCM, etc. in a packaged active modular prefabricated panel should ensure easy of assembly, low impact at worksite, reduction of space requirements inside the buildings for the storage systems, reduction of the construction and maintenance costs of Nearly Zero Energy Buildings (NZEB) or positive energy buildings thanks to prefabrication and standardization.

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| **Expected deliverables:**<br>**1.** Annual report summarizing the technology developments<br>**2.** Technological developments for active facades<br>Realization of improved performance and cost reduction of active "skins" across Europe representing various technical solutions and supply compositions | | |
| **Monitoring Mechanism:**<br>Monitoring of the market prices.<br>Monitoring of the primary energy savings, GHG emissions and technology footprint. | | |
| **TRL:** 4-5 to 7-8 | | |
| **Total budget required:** 50 m€ | | |
| **Timeline:** 5 years | | |
| **Parties / Partners**<br>(countries / stakeholders / EU) | **Implementation financing / funding instruments** | **Indicative financing contribution** |
| Italy<br>Solar companies<br>Industrial Partners (e.g. insulation)<br>Engineers, Architects (experts for facades, building technology, specific components)<br>Universities and research institutions | Ministry of Economic Development, Ministry of Education, University, and Research, funding from Regions | substantial financing contribution is intended but cannot be specified at present |
| Germany | National funding (Federal Ministry of Economics and Energy) and industry resources | 20 m€/5 years |
| Austria | National funding (Federal Ministry for Transport, Innovation and Technology) and industry | 1 m€/year<br>(still to be confirmed) |
| Swedish industrial actors<br>Universities<br>Solar companies<br>Swedish Research Council | Projects could be financed through the research funding programs of the Swedish Energy Agency | Sweden is interested in this activity, but currently cannot provide information on specific indicative financing contribution. |
| EU | EU calls in synergy with ERDF | |
| **Non-technological aspects:** The potential for the uptake of the proposed technologies is important to consider. | | |
| **Global issues addressed:** GHG emissions, improving indoor comfort levels. | | |

| **Ongoing R&I Activities (Flagship activities or not): relevant to this new activity proposal** | | | | |
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| **Name** | **Description** | **Timeline** | **Location/Party** | **Budget** |
| *ZERO-PLUS*<br>*Project ID: 678407* | Achieving near Zero and Positive Energy Settlements in Europe using Advanced Energy Technology | 10/2015-09/2019 | EU H2020<br>University of Athens | 4.2 m€ |
| *E2VENT*<br>*Project ID: 637261* | Energy Efficient Ventilated Façades for Optimal Adaptability and Heat Exchange enabling low energy architectural concepts for the refurbishment of existing buildings Funded under: H2020-EU.2.1.5.2. - Technologies enabling energy-efficient systems and energy-efficient buildings with a low environmental impact | 01/2015-06/2018 | EU H2020<br>NOBATEK | 3.4 m€ |

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| *EENSULATE*<br>*Project ID: 723868* | Development of innovative lightweight and highly insulating energy efficient components and associated enabling materials for cost-effective retrofitting and new construction of curtain wall facades<br>Funded under:<br>H2020-EU.2.1.3. - INDUSTRIAL LEADERSHIP - Leadership in enabling and industrial technologies - Advanced materials<br>H2020-EU.2.1.5.2. - Technologies enabling energy-efficient systems and energy-efficient buildings with a low environmental impact | 08/2016-01/2020 | EU H2020<br>RINA CONSULTING SPA | 6.7 m€ |
| *BRESAER*<br>*Project ID: 637186* | Breakthrough solutions for adaptable envelopes for building refurbishment<br>The overall objective of BRESAER project is to design, develop and demonstrate an innovative, cost-effective, adaptable and industrialized envelope system for buildings refurbishment including combined active and passive pre-fabricated solutions integrated in a versatile lightweight structural mesh:<br>Funded under:<br>H2020-EU.2.1.5.2. - Technologies enabling energy-efficient systems and buildings with a low environmental impact | 02/2015-07/2019 | EU H2020<br>ACCIONA CONSTRUCCION SA | 5.85 m€ |
| *e-brick*<br>*Project ID: F/050181/01-02/X32*<br>*Italian ERDF financed project*<br>*"HORIZON 2020" PON I&C 2014-2020"* | The project concerns the development of an active building component for the cladding of facades of new or existing buildings. This component will be made of reinforced polymers or composite materials or recyclable materials or bricks and integral innovative photovoltaic technology (DSSC or thin film) and energy storage (thin batteries or integrated pouch cells) able to allow energy management for optimization of (internal) resources and maximization of economic profits in the exchange with the electricity grid.<br>The project applies to the introduction in the construction process of innovative components to be used both for the construction of new buildings and for energy retrofit interventions on the existing residential and industrial heritage. | 04/2017-12/2018 | Italy | 1.7 m€ |
| *PV-HoWoSan*<br>*Project ID: 03SBE0003A-E* | The project goal is to develop a cost-efficient, structural - physical functional and secure concept for restoration of multi-story apartment buildings with PV façades. On a technical level, the integration of PV elements into a specific façade concept is foreseen, which has to be based on industrially producible components and has to be easily adhered on standard façades (short construction times). Necessary electrical components will be designed to | 11/2017-10/2021 | Demonstration building: Frankfurt, Germany | 2.14 m€ |

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| | achieve a high degree regarding the pre-fabrication status.<br>First, PV modules and PV system components (cables, connectors, etc.) need to be integrated into the façade system and designed accordingly. A test façade will be used to test the developed PV façade for physical and electrical characteristics in the laboratory. Afterwards the system is installed at the demonstration site and monitored in operation. Furthermore, additional analyses regarding techno-economic planning of PV façades, their environmental impact, their grid integration benefits as well as user acceptance are conducted. | | | |
| *Smart Green Tower*<br>*Project ID: 03SBE0005A-B* | The Smart Green Tower is to be developed and demonstrated as a solar-optimized building in multi-storey buildings with high electrical self-generation and self-use, based on a solar building envelope as well as thermal-electrical coupling to a biogas CHP. As a functional unit, not only is the PV facade addressed as a renewable energy producer, but at the same time used for shading in order to control and regulate the solar heat input into the building during the summer. By combining an innovative energy management system with intelligent management strategies, the optimization of the energy flows in the building itself (building energy performance, self-consumption, load scheduling, energy supply, energy storage) and the integration of the building into smart district concepts are made possible. | 10/2017-09/2020 | Demonstration building: Freiburg, Germany | 3.14 m€ |
| *Fassade3*<br>*Project ID: 03SBE0008* | The aim of the project is the development of a multifunctional facade element with a high degree of prefabrication. The core parts are an activated building envelope (organic photovoltaic), innovative sun protection (selective and active) and sustainable insulation materials. Another important aspect is the integration of sensor technology and an integral control concept. The developed facade elements will be demonstrated and monitored in a multi-story building to show and investigate their functionality. | 12/2017-11/2020 | Demonstration building: Kitzingen, Germany | 2.4 m€ |
| *Biofassade*<br>*Project ID: 03ET156A-I* | The target of the project is the development of a facade and insulating system using biopolymers and cellulose acetate fibers with very high insulating qualities. | 10/2018-09/2021 | DE: KIT, Rhodia-Acetow, Tecnaro, Fiber Engineering, MSIng, DITF, fischerwerke, FHG Protektorwerke | 3.4 m€ |
| *Intensified Density - a small scale densification strategy for the suburbs* | Intensified Density investigates whether a small scale densification strategy for the suburbs / intermediary cities, using modular | 2016-2019 | Austria: Graz University of Technology, | 0.25 m€ |

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| *by using modular construction* | construction, and existing infrastructure on empty plots of land, can offer a competing alternative to not only the sprawl of single family dwellings but also to large projects | | University of Applied Sciences Potsdam | |
| *50 green houses - Development and demonstration of a low-tech façade greening system* | Development of a cost-efficient all-in façade greening system („Greening-Toolkit“) including a maintenance concept, involving all trades and processes, for a broad (facing roads) implementation on facades in the urban built environment, combined with a process innovation for simplification of all necessary coordination processes | 2018-2020 | Austria: Demonstration project Tatwort, GrünStattGrau, die Umweltberatung, University of Natural Sciences BOKU | 0.8 m€ |
| *Feasibility study of prefabricated multi-active facade elements for energy renovation of multi-family houses* | The aim of the project is to investigate requirements and develop a cost-effective and large-scale applicable concept for façade renovation of Swedish multi-family buildings based on prefabricated multi-active façade elements with integrated systems for ventilation, heat recovery and renewable energy. A feasibility study (technology mapping, architectural criteria, energy and financial calculations) and concept development of the above façade elements will be carried out. The main participants are LTH and NCC with close support from a broad and experienced reference group. The project will be part of an IEA research project on multifunctional façades and the result will be presented in Sweden and abroad. | 2015-2018 | Sweden: Lund University | 0.15 m€ |

## R&I Activity 5.1-3: Digital planning and operational optimization


**Strategic Energy Technology Plan**
Action 5.1
New materials and technologies for energy efficiency solutions for buildings

| Implementation Plan – Activity Fiche | | |
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| **Innovation Target: 2**<br>Develop and demonstrate market ready solutions to reduce the construction and maintenance costs of Nearly Zero Energy Buildings (NZEB) or positive energy buildings by at least 10% compared to their costs in 2015 with a view to reach a cost reduction of 15%<br>**Innovation Target: 3**<br>Develop and demonstrate market ready solutions to reduce the average duration of energy-related construction works by more than 20% for renovation and for new buildings compared to current national standard practices<br>**Innovation Target: 4**<br>Develop and demonstrate market ready solutions to reduce the difference between the predicted and the measured energy performance to maximum 15% after the commissioning period with the ambition to reach 10% | | |
| **Title:** Digital planning and operational optimization | | |
| **Individual building** ☒ | **Neighbourhood/ District** ☒ | **Others** ☐ |
| **Activity number**: AF 5.1-3 | | |
| **Description:**<br>Today's buildings are increasingly complex "systems". This applies in particular to non-residential buildings, which are often individually planned and crafted prototypes in order to also support individual user profiles with a high level of comfort. The commissioning of such buildings requires a phase of intensive adjustment and optimisation. Even during ongoing operation, suitable skills and tools are required to constantly guarantee user comfort in an energy and cost efficient manner. However, there is often a lack of understanding about how to "correctly" use modern heating and ventilation technology as well as about the functions and concepts of building operational management using appropriate systems. Normally, users can intervene individually, because this increases the acceptance and personal comfort. Their behaviour can be contrary, however, to the energy and comfort concept, for example when windows are opened in winter or high summer. That is why well-designed human-technology interfaces are just as important as information campaigns about how the building functions. In many new-build and refurbishment projects, the systems for the building operational management are examined in particular detail and scientifically evaluated in terms of the building's energy efficiency performance, user behaviour and user satisfaction.<br>BIM-based, automated fault detection and diagnostic: Energy efficiency measures in new and existing buildings often suffer from faulty operation and lack of timely and precise maintenance, jeopardizing the energy and economic savings-potential. Moreover, faulty behavior, such as incorrect hydronic balancing of heating systems or thermal bridging due to bad workmanship, may go unnoticed for long periods. Therefore, automated fault detection and diagnostics (FDD) should be developed and demonstrated to identify, and even predict, technical faults in the building based on on-board measurement data. These methods can significantly reduce maintenance costs while improving the energy efficiency of buildings. Moreover, they can significantly reduce cost and disruptiveness of renovation and maintenance.<br>GIS-based district and city energy assessment: Renovations of neighborhoods or deployment of e.g. 4th generation district heating systems can be cost-effective ways to reduce the energy use and $CO_2$ emissions while increasing the penetration of renewables in the energy system. However, the value of such large-scale projects is strongly dependent on the actual district | | |

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| context, e.g. density, building typologies, location, available RES… Especially the building energy characteristics are often uncertain leading to high uncertainties on the predicted costs and benefits of such district energy projects. Therefore, this activity aims at combining statistical and technical building energy data to improve predictions of the building energy demand, including the spatial and temporal variability and uncertainty. A further goal is to update and upgrade the building energy assessment methods. These are considered to be a key driver in the transition towards a carbon neutral housing stock. Energy assessment methods are needed to judge compliance with energy performance regulations, to increase transparency in real estate transactions, to monitor the energy efficiency of the building and to help planning energy saving retrofit measures and to foster control and autocontrol of the quality of renovation works. | | |
| **Impact:**<br>Projects in this topic will contribute to facilitate a correct potential analysis of predicted operational costs and benefits.<br>Projects in this topic will contribute to reduce the time and cost needed to identify and diagnose inefficient operation of buildings and their technical systems by exploiting the benefits of BIM in the FDD framework. As diagnostics will become more precise, these tools will contribute to reduce the costs and overhead related to maintenance and faulty operation.<br>Projects in this topic will contribute to identify neighbourhoods or districts with expected high potential for large-scale energy investments. More importantly, the developed tools should facilitate a correct potential analysis including risk-assessment. In addition, more detailed knowledge on the spatial and temporal variability will facilitate the development of tailor-made energy renovation packages on a neighbourhood or district level.<br>Developing future-proof building energy assessment methods will support the transition to a carbon neutral housing stock, while assessing the techno-socio-economic impact at the individual building, the local grid and the building stock level. A specific challenge is to merge and integrate regional approaches across the EU. | | |
| **Expected deliverables:**<br>Combination of Hard- and Software to be implemented and running together with / or replacing an existing building automation system. | | |
| **Monitoring Mechanism:**<br>New wireless technologies of smart metering / monitoring. | | |
| **TRL:** 5-6 | | |
| **Total budget required:** ~250 m€ | | |
| **Timeline:** 5 years | | |
| **Parties / Partners**<br>(countries / stakeholders / EU) | **Implementation financing / funding instruments** | **Indicative financing contribution** |
| Belgium (Flemish Region) | National/regional Funding : Flemish agency “Flanders Innovation & Entrepreneurship” and the Research Foundation Flanders(open and competitive call for proposals)<br>EU funding | 5 m€/5 years (estimation, since bottom up non thematic funding programmes) |
| Austria | National funding of Calls for projects on an annual basis (research projects with different stakeholders) | 5 m€/5 years<br>(still to be confirmed) |
| Germany | National funding (Federal Ministry of Economics and Energy) and industry resources | 20 m€/5 years |
| Italy<br>Industrial Partners<br>Engineers, Architects | Ministry of Economic Development (MISE), Ministry of Education, University, and | substantial financing contribution is intended but cannot be specified at present |

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| Universities and Research Institutions | Research (MIUR), funding from Regions, possible use of the Fund for the development of the national power grid managed by Ministry of Economic Development (MISE) and ERDF | |
| Sweden | Swedish Energy Agency, industry resources, Swedish Research Council | Sweden is interested in the activity, but currently cannot provide an indicative level of financial contribution. |
| France | National Digital Transition Plan; Ministry for the Ecological and Inclusive Transition - Ministry of Territorial Cohesion | > 10 m€/4 years |

**Ongoing R&I Activities (Flagship activities or not): relevant to this new activity proposal**

| **Name** | **Description** | **Timeline** | **Location/Party** | **Budget** |
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| *Several R&I projects* | https://lirias.kuleuven.be/cv?u=U0097128 | | Energyville/KULeuven | |
| *OOM4ABDO Joint research project: Object-oriented monitoring as a basis for more efficient operation, as well as costeffective optimization of exisiting buildings through the utilization of machine learning-techniques, the application of virtual laboratories and the augmented, "transparent" operation of buildings and districts Project ID: 03SBE0006A-B* | The scope of the project is to identify and utilize untapped saving-potentials in building performance operations. The object-oriented monitoring provides the buildings operator with all the extracted and structured measurement data. A cloudbased infrastructure enables automated indentification of inefficiencies and abnormal behaviour in facility-operations. Machine learning-methods and the correlation between measurement data and dynamic models enable constant improvements and the implementation of advanced building controls. | 12/2017-11/2022 | Germany: werkkraft GmbH, RWTH Aachen | 2 m€ |
| *SmallCAN: Demonstrationsanlage einer integrierten Gebäudeautomatisierung mit flexiblem Gerätespektrum und flexibler Konfiguration. (Cost-effective decentralised fieldbus system tested). Project ID: 03ET1016A* | On larger buildings with complex building technology, integrated automation can lead to considerable energy savings. Yet systems readily available on the market are often not utilised due to the costs involved or are unable to realise their full energy efficiency potential owing to deficient flexibility or extendibility. With the SmallCAN field bus system, a large number of sensors and devices can be integrated affordably and in a simple topology as bus subscribers. A | 10/2011-10/2018 | Germany: TU Braunschweig | 0.4 m€ |

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| | special characteristic of SmallCAN are the low energy requirements for the entire automation system. It is furthermore relatively simple to implement, as it is not usually necessary to program the bus subscribers individually. | | | |
| *BIM2SIM*<br>*Methods for the Generation of Building Performance Simulation Models out of Building Information Modeling Data.*<br>*Title of Subproject: Development of methods, workflow automation and interfaces.*<br>*Project ID: 03ET1562A-B* | It is thus the aim of this project to develop methods and tools focussing on creating executable simulation models out of data models such as building information model (BIM). The methods and tools will reduce the effort to create simulation models and will support the use of modern simulation techniques in the building sector. To consider the energy use throughout the building lifecycle, the project encompasses the development of methods to represent aspects of embodied energy in BIM. The targets of this project are accompanied by the aim to perform related simulations and transfer simulation results back into BIM. | 05/2018-04/ 2021 | Germany: RWTH Aachen, Rud. Otto Meyer Technik | 1.2 m€ |
| *SIMQUALITY*<br>*Title:Development of Quality Standards of Planning Tools for Building Energy and District Simulation.*<br>*Project ID: 03ET1570A-F* | SimQuality focuses on the integration of building energy simulation programs into the planning process. For the realization of this goal, independent test methods have to be developed, which are suitable for improving the planning process as well as the legal certainty for software developers and practitioners. This includes:<br>• Compilation of a matrix of requirements (considering modelling depth, user requirements, simulation speed, etc.) for representative application scenarios within the planning process<br>• Development of new validation procedures and standardized input data sets and reference results<br>• Formulation of a practical guide and quality requirements for engineers and planers for application of building energy simulation programs | 08/2018-07/ 2021 | Germany:<br>TU Dresden, RWTH Aachen, HS München, Hottgenroth Software, INNIUS DÖ, IB Scholz | 2.6 m€ |
| *BIM4BEMS - Building Information Modeling for Building Energy Management Systems* | BIM4BEMS explores use cases that represent the usage of building information models (BIM) in combination with | 2016-2019 | Austria: AIT, Vienna University of Technology, Caverion Austria | 0.7 m€ |

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| | building energy management systems (BEMS) during operation. This enables the interaction between BIM and building management systems (BMS) which improves the analysis and visualization of inefficiencies in facilities. | | | |
| *BIMSavesEnergy - BIM-based planning-methods for the assurance of energy-efficiency in the building process* | The Building Information Model (BIM) brings about fundamental changes in the planning and construction of buildings, as the common base makes it possible to work closely together across disciplines in construction projects. In this project, BIM-based planning methods are developed, which make the influence of planning decisions on energy efficiency quantifiable and controllable in the management process. | 2017-2019 | Austria: AIT, CES clean energy solutions, ISIS Papyrus Europe, CYPE SOFT, Bauunternehmung GRANIT | 0.5 m€ |
| *6D BIM-Terminal: Missing Link for the development of CO2 neutral buildings* | The present project aims to close the gap between specialist consultants and Building Information Modeling (BIM) applications. For that, relevant data for cost estimation, scheduling construction planning and management or sustainable building operation and facility management, shall be added automatically to BIM elements and imported into the respective specialist planning software. This data exchange shall be carried out using IFC interface according to ÖNORM A6241-2 and the properties of the ASI properties server via a central platform, the "6D BIM-Terminal". | 2017-2019 | Austria: IBO, ib data, baubook, Güssing Energy Technologies, AEE INTEC, A-NULL Development | 0.3 m€ |
| *SCI_BIM - Scanning and data capturing for Integrated Resources and Energy Assessment using Building Information Modelling* | The aim of the project is to increase the resources- and energy efficiency through coupling of various digital technologies and methods for data capturing (geometry and materials composition) and modelling (as-built BIM), as well as through gamification. | 2018-2020 | Austria: University of Technology Vienna, ZAMG | 0.6 m€ |
| *AR-AQ-Bau*<br>*Use of Augmented Reality for acceptance and quality assurance on construction sites* | The aim of this research project is the development of a construction site-suitable augmented reality (AR) system included a Remote-Expert-System and a BIM-Closed-Loop data transfer system for improving the quality of construction, building security and energy efficiency as well as increasing the efficiency of | 2018-2020 | Austria: University of Technology Vienna, FCP Fritsch, Chiari & Partner, ARIOT OG, Daqri Holographics | 0.6 m€ |

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| | construction investigation | | | |
| *Kroqi* | Digital public collaborative platform, free-of-charge for all construction professionals. This platform allows the management of data and projects. It might host any service and software working in BIM. The platform aims to accelerate the adoption of BIM by professionals. It allows in particular to check the quality of data for the various services (characterise the readiness of the model) among which, ultimately, energy simulation. | 2016-2022 | France, PTNB (National Digital Transition Plan) | 8 m€ |
| *Dictionary of objects and properties in BIM* | The National Digital Transition Plan (PTNB) has initiated the development of a dictionary of BIM objects and properties in order to better structure data, facilitate use and exchange for all kinds of usage (design, numerical simulation, etc.) or software. Nearly 300 objects and 3000 properties would be documented in the database and updated via a dedicated and open process. In the long term, the dictionary is intended to be enriched by the object properties relating to safety, health and energy and environmental performance. | 2016 -2020 | France, PTNB | 3 m€ |
| *Digitisation of construction regulations* | The purpose of the experiment is to translate regulatory texts into BIM and set up automatic checking of these texts. The goal is to automate the 'processing' of regulatory texts to facilitate and standardize their use in software aiming to control these rules. | 2016-2019 | France, PTNB | 2 m€ |

## R&I Activity 5.1-4: Living labs - Energy technologies and solutions for decarbonized European quarters and Cities


**Strategic Energy Technology Plan**
Action 5.1.4
New materials and technologies for energy efficiency solutions for buildings

| Implementation Plan – Activity Fiche |
|---|
| **Innovation Target: Living labs**<br>Establish *livings labs* as a format to<br>- Tackle transition of our end-use energy systems towards climate-neutrality<br>- Open our economy for a competition of innovation with to some extent disruptive character.<br>- Develop and demonstrate market ready solutions to reduce considerably the retrofit, construction and maintenance costs of Nearly Zero Energy Buildings (NZEB) or positive energy buildings.<br>- Support communities with high resource and energy efficiency, an increased use of renewable energy production<br>- Introduce the ICT in the development of decarbonized communities<br>- Define renovation solution for circular communities |
| **Title:** Living labs - Energy technologies and solutions for decarbonized European quarters and Cities |
| **Individual building** ☒ **Neighbourhood/ District** ☒ **Others** ☐ |
| **Activity number**: AF 5.1-4 |
| **Description:**<br>The responsibility for climate-neutral buildings and neighbourhoods goes beyond national borders. That is why internationalization in the field of concept development for energetically pioneering buildings and neighbourhoods is a main target. The object of the living lab innovation target is to establish the concept for an international "energy competition" by intensifying transfer from research and innovation into building practice by means of wider application and demonstration of outstanding energy concepts for buildings and neighbourhoods in one European competition format, which is currently lacking. A huge amount of similar initiatives will not master the challenge! Under this systemic competition approach, the energy system and end-use technologies in buildings are integrated. Energy management, monitoring systems and smart technologies, synergies between different energy sectors and infrastructures will be leveraged in order to achieve optimal solutions for the regional or local energy systems as well as for the overall European energy system. Local integration from different heat sources of different temperature levels, including unused recoverable energy and the integration of district heating and cooling will be demonstrated.<br>Furthermore, the activity aims to promote the transition from the current Solar Decathlon Europe (SDE) competition format (Hungary 2019)[3] towards a more permanent living lab for a climate-neutral habitat integrated into urban space in a sustainable and organic manner, while taking users and economy into deeper consideration. The regularity and excellence within the competition format will have motivating impact on society creating innovation environments all over Europe that initiate economic rethinking towards the post fossil fuels age. |
| **Impact:**<br>- High Public awareness for the common goal and individual share for climate-neutrality through regular *Living Lab Europe Competition* (5 year interval fitting with EUSEW)<br>- High transparency with regards to competitive energy technologies and concepts |

[3] http://solardecathlon.eu/congrats-szentendrehost-city-sde19gratulalok/

- Speeding-up transfer for more efficient /sustainable technologies

Projects in this topic are the former playgrounds of the *Living Lab Europe Competition* (LLEC) that permanently contribute to identify communities resilient to the climate change. In addition, they will facilitate the development of energy renovation packages on a community level demonstrating strengths and weakness under the almost objective conditions of the living lab. These living lab communities will have lighthouse character for the transition to a carbon neutral housing stock.
Climate-neutral quarters and districts share the attribute of mixed uses and building codes (residential, non-residential, special use), including the interaction of residents with the built environment. The cornerstones of such a quarter or district can be summarized as follows:

- A quarter or district that on an annual basis produces energy that it consumes climate-neutral
- Interlinking of smart technologies and services targeting at user-requirements (Smart City)
- Integrations of mobility services
- Development of new, innovative business and sharing models
- Focus on power self-supply making use of innovative grid and storage technology
- Energy-efficient and intelligent appliances (Smart Building)
- Sustainable and ecologic building materials and products
- Fully digitalized planning, construction and operation of quarters and districts (BIM)

**Expected deliverables:**

1. Living Lab Europe Competition as central public event (2025/.30/.35/.40/.45…) tackling awareness and consensus for transition
2. Demonstration of 5 climate-neutral quarters and districts in different European climate zones until 2050 (former LLEC-sites)
3. Plausible and harmonized system boundaries and definitions of climate-neutral quarters and districts
4. Technological developments for the realization of climate-neutral quarters and districts
5. Development of market ready concepts and solutions for climate-neutral quarters (technical, legal, commercial, administrative)
6. Accompanying measures in order to prevent rebound effects and cascade effects

**Monitoring Mechanism:**
Living Lab Europe Competition will develop general monitoring mechanisms for the different competition formats (from single technologies to complex urban energy systems) building on the SDE-Monitoring-requirements.

**TRL:** 5-9

**Total budget required:** 150 m€ (~ 20 m€/y until 2025)

**Timeline:**

1. Preparative work form 2019 until call for 1. LLEC in 2020 at EUSEW
2. LLEC design and building competition 2020-2024; accompanying research & development
3. 1. LLEC 3 Months in 2025 (expo, competitions, conferences)
4. post LLEC phase with smart monitoring for min. 10 years (2025-2035)

| **Parties / Partners** (countries / stakeholders / EU) | **Implementation financing / funding instruments** | **Indicative financing contribution** |
|---|---|---|
| Germany | National funding (Federal Ministry of Economics and Energy) and industry resources | 50 m€/7 years |
| Austria | National funding (Federal Ministry for Transport, Innovation and Technology) and Industry | 5 m€/5 years |
| France | Ministry for an Ecological and Inclusive Transition; CEREMA; Ministry of territory cohesion; ANR | Intended contribution of 8 m€/4 years |

| | | |
|---|---|---|
| Sweden | Swedish Energy Agency, Swedish Research Council, Swedish Innovation Agency and the industry | Sweden is interested in the activity, but currently cannot provide an indicative level of financial contribution. |
| Italy<br>Industrial Partners<br>Engineers, Architects<br>Universities and Research Institutions | Ministry of Economic Development (MISE), Ministry of Education, University, and Research (MIUR), funding from Regions, possible use of the Fund for the development of the national power grid managed by Ministry of Economic Development (MISE) and ERDF | substantial financing contribution is intended but cannot be specified at present |

**Non-technological aspects:**
The past decades of energy research and very successful technological developments do not correlate with the poor improvement of efficiency and performance at EU or national level. Structural change and transformation does require novel economic schemes and social acceptance- otherwise R&D will not have needed impact. Living labs can fill this gap by establishing a long term competition format holistically addressing the needs.

**Global issues addressed:**
The challenge to achieve the goals for climate protection set in Paris 2015 does require an open format in the meaning of intensifying international collaboration, technological as well as economical structural changes.
Living labs as here addressed fill gaps of contemporary funding schemes at EU-level. The huge number of activities jointly does not have the obligatory impact for transformation at European scale.

**Ongoing R&I Activities (Flagship activities or not): relevant to this new activity proposal**

| **Name** | **Description** | **Timeline** | **Location/Party** | **Budget** |
|---|---|---|---|---|
| *Solar Decathlon Europe 2010 & 2012 in Madrid* | Organization and Hosting of SDE 2010 & 2012 and Spain participation | 2008-2013 | Spain/ UTMadrid | ~30 m€ |
| *Solar Decathlon 2013 in Irvine, California* | Support for the winning team | 2011-2014 | Austria/ Vienna University | ~0.5 m€ |
| *Solar Decathlon Europe 2014 in Versailles* | Organization and Hosting of SDE 2014 and French participation | 2012-2015 | France/ CSTB Solar SAS | ~ 20 m€ |
| *Solar Decathlon 2017 in Denver, Colorado* | Support for the winning team | 2015-2018 | Switzerland/ EPF Lausanne | ~ 0.5 m€ |
| *SOLAR DECATHLON EUROPE 2014, German Participation* | Three teams were supported to take part in the SDE 2014 in France (Versailles). As in 2012 the public funding was only a minor part after sponsoring and own resources of the universities. Since 2007 when a first German Team won SD in Washington the SD played a major role in the educational sphere which increasingly inspired industry partners. (03ET1238A-C) | 2013 - 2015 | DE/ Frankfurt University of Applied Sciences; Erfurt University of Applied Sciences;<br>UdK Berlin | 0.94 m€ |
| *EG2050: EnEff2050Begleit* | Accompanying research designated to competition for climate neutral building stock. Within this activity in 2017 a call for concepts for international energy competition took place. The wining living lab concepts "Energy Endeavour Competition Cottbus" as well as the second price "Solar Decathlon Goes Urban" are under assistance. (03EGB0006A-C) | 2017–2020 | DE/ BUW; FhG-ISE; ALUF | 2.6 m€ |
| *European Energy* | Intension to develop the SDE further towards | 2015-2021 | DE/ BUW | 0.34 m€ |

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|---|---|---|---|---|
| *Endeavour* | a more European and integral approach. A strong relation to relevant programs of the International Energy Agency mirrors the scientific and systematic goal to bundle the numerous activities and competitions. | | | |
| *GrünStattGrau – Innovations for Greening Cities "The green living laboratory"* | GrünStattGrau represents the holistic of competence for green building technologies such as green roofs and living walls in Austria. It generates impulses for urban green infrastructure on buildings and links innovative products and projects, supports through know-how and analysis for implementation processes. GrünStattGrau guides urban and participatory strategies from development to implementation. | 2017-2022 | AT | 1 m€/ 5 years |
| *Innovation lab act4energy* | The Innovation Lab act4energy is set up as an innovation laboratory project. Its focus is to solve the problems of renewable energies integration with a focus on photovoltaic power paired with local consumption, linked to the high fluctuation of renewable energies. | 2017-2022 | AT | 1 m€/ 5 years |
| *PREBAT Program – Nearly zero energy demonstrator buildings* | Actual energy performance measurement of 200 demonstrator buildings, with a survey of the way of living inside these buildings. Includes comparison between simulated and actual energy performance; estimations of the impact of weather conditions and of the way of occupying the building; comfort of occupants; global costs compared to standard buildings. | 2012-2020 | France (Ministry for an Ecological and Inclusive Transition; CEREMA) | ~0.9 m€/y |
| *Improved borehole technology for Geothermal Heat Pumps development* | Investigating innovative technologies (borehole heat exchangers and thermal response testing) within the field of geothermal heat pumps to provide more efficient and cost effective borehole systems, and to increase the areas where the technology could be used. These actions will provide the industry with tools to further increase the technology penetration into the market place. Increase in adoption of geothermal heat pump is key for the reduction of the overall energy use for heating and cooling of buildings. How? The KTH live-in-lab platform will be utilized as test beds to test innovative heat exchangers design, long boreholes, along with new methods of thermal response testing, i.e. for the assessment of ground properties. Energy performance and economical profitability as well as feasibility of the investigated innovations will be assessed through monitoring and testing. | 2017-2019 | Sweden: The Royal Institute of Technology (KTH) | 0.3 m€ |
| *KTH – Live-in-Lab* | The idea of KTH Live-In Lab sprung out of this context as a testbed for new technologies, capable of improving the way we build, and accelerate the innovation rate in the contruction and residential sectors. KTH Live-In Lab was established during 2016 with the help of a donation from Einar | 2017 - | Sweden: The Royal Institute of Technology (KTH) | Various amounts from different public and private actors. |

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| | Mattsson as well as the contribution of VINNOVA, Boverket, Semrén & Månsson, Ericsson, Belkab, Grunditz Göransson Arkitektur and Pinnab Inneklimat. The testbed's three on-campus buildings will stand ready to receive their first residents in the autumn of 2017, and at the end of the same year the 300 sqm innovation-area, at the bottom of one of the buildings, will be inducted into service. Up until the testbed is launched, the work of KTH Live-In Lab is focused on collecting and matching the various test and research projects that will be part of the initial testbed constellation. KTH Live-In Lab has access, through a ten-year leasing agreement, to the 300 sqm innovation area that is exempt from building permit regulations, providing unique possibilities for testing. Within the innovation area several test-apartments will be built and allow for testing of how different building geometries interact with the technologies and the user. During the same period we will be able to collect and analyze measurement data from the remaining apartments (student apartments) as well as "undervisningshuset" and other buildings on campus. | | | |
| *HSB – Living lab* | The HSB Living Lab is a cooperation between three organisations: HSB Housing Corporation, Johanneberg Science Park (JSP) and Chalmers University. This Living Lab will primarily be created as a residential building for students, located on the Chalmers campus in Gothenburg, Sweden. The architectural firm Tengbom constructs design of the house. Research will be conducted in close collaboration with the Chalmers and Gothenburg Universities and the results will be used by HSB to develop the homes of tomorrow.<br>The HSB Living Lab<br>- has a ground space of 400 m2 and will be on three floors.<br>- will have a total of about 25 apartments for students and guest researchers. These student units will be flexible and it will be possible to change the layout over the ten year duration.<br>- includes other facilities like an exhibition area, a common laundry room and a meeting area.<br>- is a cooperation between HSB (a cooperative housing association with 550.000 members) and a management team with representatives from Chalmers, Interactive Institute and NASA. | 2015 - | Sweden: HSB | Various amounts from different public and private actors. |
| *PACTE Program – Performance of the building envelope* | 2 projects: MERLIN and EPILOG aim at developing operational methods to have an onsite measurement of performance of building envelope: improvement of reliability, decrease of the time needed for | 2016 - 2019 | France (Ministry for an ecological and inclusive transition / Ministry of | 1.3 m€ |

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| | measurement, etc. The method will assess the intrinsic performance of the building (independent from external phenomenon such as weather, climate, inhabitants behaviors) which would ultimately allow to measure more precisely construction and renovation works performances, improving legal framework and autocontrol for developers and construction enterprises. | | territory cohesion) | |
| *RESBATI – Onsite energy performance measurement of building walls* | The RESBATI project (in-situ measurement of the thermal resistance of building walls) aims at developing an in-situ measurement device that guarantees a general measurement: use on any type of wall and at any time of the year, low measurement duration, ease of use, moderate cost. The measuring means is infrared thermography in active approach. The uncertainty and the limitations of the measurement will be identified during the project. | 2016-2019 | France: ANR | 0.7 m€ |
| *Program to be confirmed – Performance of the building envelope* | Continuation of the projects MERLIN and EPILOG | 2018-2021 | France | Estimated at 5 m€ |

## Activities Action 5.2

### R&I Activity 5.2-1: Cost-efficient, intelligent, flexible heat pumps (also thermally driven) and heat pumps for high temperatures


**Strategic Energy Technology Plan**
Action 5.2
Cross Cutting Heating and Cooling Technologies for Buildings

| Implementation Plan – Activity Fiche | | |
|---|---|---|
| **Innovation Targets:**<br>Heat Pump Systems: Cost reduction for small and large size heat pumps by 50% (compared to 2015 market price), development of prefabricated, fully-integrated 'plug in and play' hybrid/multisource heat pump systems and integrated compact heating/cooling plants based on modular heat pumps. | | |
| **Title:** Cost-efficient, intelligent, flexible heat pumps (also thermally driven) and heat pumps for high temperatures | | |
| **Individual building** ☒ | **Neighbourhood/ District** ☐ | **Others** ☐ |
| **Activity number**: AF 5.2-1 | | |

**Description:**

Heat pumps are widely recognized as a key technology to reduce $CO_2$-emissions in the residential building sector, especially when the electricity-generation system is to decarbonize by means of large-scale introduction of renewable electric power generation sources. According to a study for the European Het Pump Association, large-scale introduction of heat pumps could reduce $CO_2$-emissions by 34% to 46% in the building sector of certain European countries by 2030.

Development of an easy to install cost competitive heat pump kit for houses with existing non-electrical boiler:
The existing boiler will be kept and will only be employed as a back-up system under extreme ambient conditions when the heat pump is not able to attain 60°C or to increase the temperature of the sanitary hot water or an efficient level of heating production. The design of the components should be made easy for integration and installation with the boiler heating system. This should ideally be wall mounted recognizing current form factors and the installer work-flow.

Development and deployment of high temperature heat pumps for industrial processes and DHC:
Aim is the development and demonstration of electrically and thermally driven heat pumps in individual industrial applications as well as in combination with district heating and cooling networks including thermal energy storage. The heat pump should have a compression refrigeration cycle based on low GWP refrigerants working fluids for use in medium temperature industrial applications (condensation temperatures up to 170°C and evaporation temperatures up to 100 °C) and district heating (condensation temperatures up to 50°-70° and evaporation temperatures of 30°-40°). Applications of the heat pumps include process heat generation as well as waste heat recovery in industrial processes yielding substantial increases in energy efficiency. For the district heating application the additional use of micro booster heat pump (2 KW) could further improve the efficiency of the network.

Intelligent heat pump controlled to deliver extra services in the grid:
If more heat pumps are put in the grid, more issues could arise such as the need for more peak power capacity and unbalances between phases in the grid. A need arises to control the heat pump in a smarter way in order to reduce peak

demand and to support the grid with extra services. To complete controlling the heat pump based on the heat demand of the building, the heat pump can also be controlled based on input from outside like availably of renewable energy sources or energy prices. In order to enhance the conform level in the building (both room temperature and hot tap water) thermal storage in the building mass, underground or in water storage tanks is needed. To deliver extra services to the distribution grid some extra features need to be integrated in the inverter of the heat pump.

Interoperable Flexible Heat pump:

- Creation of heat pump models for the design exploration: analyzing impact on capex, opex, lifetime, efficiency and balancing these against Demand Response services provision
- Investigation of the use of hybrid modelling and inverse modelling together with data analytical models, to extract an actual physical model enhanced with valuable parameter information by means of data analytics and self-learning techniques.
- Design exploration and simulation on the heat pump model, and for different business case scenarios. This also includes an analysis of the business with the coupling of the heat pump with geotabs. In this case, heating is realized through the GEOTABS and a secondary system, a split will be made between a socalled “base load” that will be provided by the GEOTABS and the remaining energy needs that should be supplied by a secondary system e.g.
- Definition and prototyping of a heat pump controller for such a flexible heat pump based on sensors/observables, and being able to determine safe operating ranges for the next n time steps
- Definition and prototyping of a standard (interoperable) interface between the heat pump controller and a BEMS/HEMS, allowing the BEMS/HEMS to determine optimal and secure control plans for the flexible heat pumps based on the received information from the heat pump controller, and communicate these control decisions in a standard interoperable manner towards the heat pump controller
- Exploration of the use of control means at a deeper component level. This results in two main technical advantages: (1) The data from the sensors that are embedded within the heating and cooling systems can be used to improve the control algorithms (2) The algorithms can be tailored and optimized and are more robust compared to pure data based models with neural networks. In addition to improving the system performance, through this smart thermostat additional information from the use of the heating and cooling systems will be available to the end customers and any other relevant information, e.g. comfort if possible
- Lab level validation.

Further development and roll-out of absorption technologies to increase the utilization of district, waste and renewable heat sources:
Thermally driven cooling systems can contribute to the increased use of renewable and recovered heat for cooling in general and for an increased use of readily available heat sources from District Heating in particular. Using these technologies therefore allows for an increase in the utilization of the former as well as increased efficiency in the latter while potentially also increasing the share of the former in the latter. To increase and improve the use of absorption chillers the following is needed:

- Further develop thermally driven cooling technologies with the specific aim to decrease the needed input temperatures down to 55°C
- Further develop and demonstrate concepts for the utilization of DH return flows for cooling
- Further develop and demonstrate concepts for the utilization of off-season DH for cooling
- Develop and demonstrate concepts for the additional utilization of waste streams through DH for cooling.

Gas sorption heat pump systems for different applications and climatic areas:
The role assigned in the future European market scenarios to Gas Ab/Adsorption Heat Pump (GAHP) technology, as heating solution for residential and light commercial applications, is significant. For example, if half of the 80 million of old and inefficient, non-condensing oil and gas boilers installed in EU buildings, would be substituted with gas driven heat pumps, the total European energy consumption could be reduced of about 5% in primary energy terms. Some European heating sector manufacturers are in the last phase of development of a new generation of gas driven sorption heat pumps. These are in the process of entering the residential heating market sector. Instead commercial products are already available for

tertiary sector end users (in the capacity range up to approx. 70 kW). The main challenges for the GAHP technology supply chain today are related to the need to reduce the perceived market risk: customer acceptance; legislative barriers; political perception; etc. In particular, there is small experience in the comparison of laboratory and real operation GAHP installation performances. There is a lack of awareness and trust on the technology from most of the stakeholders: general public, decision makers, installers, planners, etc. The insufficient number of existing installations reflects in a reduced experience on planning, installation, commissioning, operation and maintenance of these systems. Moreover there is the need to define and test standard procedures and certification schemes for this category of renewable heating generators. The actual status of deployment does not allow identifying the optimal GAHP heating systems configurations in the different European boundary conditions (climates, building types, heating system typologies). Furthermore few analyses have been carried out at present on lifecycle cost and environmental assessments for the considered GAHP generators and production processes. Aim is to demonstrate, on a large scale (up to 10.000 units) gas driven heat pump systems for different applications and climatic areas. Monitoring the performance of the systems operation in real operation conditions and create the know-how base to develop the appropriate tools for overcoming the technology deployment barriers. In particular, establish the basis for a comprehensive qualification system of functions involved in the European supply chain such as planners, installers and service companies to avoid possible mistakes and ensure optimum deployment of GAHP technology from the outset. Set out EU wide guidelines for the correct planning, installation, commissioning, operation and maintenance of GAHP. Raise awareness and generate trust on GAHP for a faster technology deployment. Part of the project activities should be devoted to identify the most suitable GAHP heating systems configurations in different European (boundary) conditions: different climates, building typologies, heating system types (emission, distribution, etc.), and local regulations. The proposal should contribute to the definition and test of standard procedures and certification for GAHP. As well as present comparisons between laboratory and real operation performance of the installations and provide further data for product development. The proposal should include lifecycle cost and environmental assessments for the considered GAHP and their production processes.

**Impact:**

Development of an easy to install cost competitive heat pump kit for houses with existing non-electrical boiler:

- Gas consumption reduction
- A sCOP between 4-5
- Easier and quicker installation
- Cost reduction (especially for installation).

Development and deployment of high temperature heat pumps for industrial processes and DHC:

- Demonstration of the heat pump in operational environment
- Smart use of waste heat as a sustainable source for the local DHC grid
- Cutting energy cost and CO2 emission of industrial processes
- Lowering the production cost of the heat pump
- Standardization of installation.

Intelligent heat pump controlled to deliver extra services in the grid:

- Increased self-consumption of locally produced RES by the heat pump
- Reduced procurement cost of the heat pump loads by shifting the operation of the heat pump to low cost periods
- Unbalance compensation in the distribution grid by the intelligent inverter

Interoperable Flexible Heat pump:

- Reduced heat-pump payback time by enabling Demand Response services incentive earning opportunities
- Thereby increase their adoption rate and accelerate the efficient electrification of heating.
- Increased amount of controllable flexible loads that are needed to support the increased amount of variable RES electricity in a load follows generation control scheme.

Further development and roll-out of absorption technologies to increase the utilization of district, waste and renewable heat sources:

By increasing the use of thermally driven cooling technologies, more traditional cooling technologies can be replaced through the utilization of available resources while improving efficiency and supply composition of existing thermal networks:

- Replace electricity driven cooling technologies and decrease the impact of cooling on the system
- Increase the utilization of thermal resources for cooling in summer
- Increase the efficiency of DH systems by increased utilization of return flows

By decreasing the temperatures that are needed for absorption technologies a whole range of additional sources for thermally driven cooling would be available or usable impacting not just the way cooling is provided but also the efficiency and structure of DH networks and influencing the electricity network:

- Even further decrease the impact of cooling on the electricity system
- Increase the availability of thermal resources to be utilized for cooling in summer
- Increase the applicability of DH systems for the increased utilization of return flows
- Increase the flexibility of low-temperature DH networks.

Gas sorption heat pump systems for different applications and climatic areas:

- Accelerate the large scale adoption of high efficiency heating and domestic hot water preparation through the use of renewable energy
- Large deployment (up to 10.000 units) of gas driven heat pump systems for different applications and climatic areas
- Measured primary energy savings and GHG emission savings relative to the alternative best available solution
- Generate trust and awareness on GAHP to overcome the non-technical barriers
- Implement optimization at system level and standardisation of technical solutions.

**Expected deliverables:**

Development of an easy to install cost competitive heat pump kit for houses with existing non-electrical boiler:

- Hot water production with a temperature lift of minimum 55 K
- Heating temperature in the range of 35° to 55°C
- Optimal management and automatic operation of the heat pump unit and boiler
- Development of a compact design in a form of kit with all the necessary components for an easy integration and installation with the boiler heating system.

Development and deployment of high temperature heat pumps for industrial processes and DHC:

- Design of components to use low GWP refrigerants (HFO, natural refrigerants)
- Improved compressors and lubrication methods for high evaporating temperatures (up to 100°C)
- Standardisation and classification of processes (temperature levels, time-based energy demand, etc.)
- Process integration of industrial heat pumps (control and hydraulic design)
- Impact of heat pumps on existing process (dynamic behaviour)
- End product cost savings in industrial process.

Intelligent heat pump controlled to deliver extra services in the grid:

- Dimensioning tool to optimize thermal energy storage for the heat pump to increase self-consumption of locally produced electricity
- To develop a thermos-hydraulic model for metal foam/porous materials enhanced latent thermal energy storage, using the model to design and optimize metal foam/porous material-PCM combinations for custom energy – and power densities.
- Self-learning algorithms to predict the energy demand (room heating and hot tap water) to be used as input to optimally control the heat pump
- Adapted inverter for heat pump with advanced grid monitoring system and unbalance compensation
- Test results of intelligent controlled heat.

Interoperable Flexible Heat pump:

- Novel heat pump design providing greater flexible operating range and control facilities
- Model of such a flexible heat pump
- Novel and standardized control interface to control the heat pump’s operation by a BEMS/HEMS for multiple flex

- business cases
- Proof-of-concept prototype for lab validation.

Further development and roll-out of absorption technologies to increase the utilization of district, waste and renewable heat sources:

- Annual report summarizing the technology developments
- Technological developments for absorption chiller solutions
- Overview over design solutions for direct and return flow integration of absorption technologies for different types of use (e.g. seasonal, annual)
- Realization of improved performance in 5 DH networks across Europe representing various technical solutions and supply compositions.

Gas sorption heat pump systems for different applications and climatic areas:

- Dissemination of the summary of performance monitoring campaign results to the relevant stakeholders
- Design guidelines for the correct planning, installation, commissioning, operation and maintenance of GAHP including integration schemes for different European (boundary) conditions and best practice illustration
- Contribution of CEN-TC299 with the definition and test of standard procedures and certification for GAHP.

**Monitoring mechanism:**
National authority in coordination with sector's experts.
Comparison between a heat demand controlled heat pump and an intelligent controlled heat pump

- Increased self-consumption of locally produced RES by the heat pump
- Reduced procurement cost of the heat pump electricity load by shifting heat pump operation from peak price hours towards off-peak periods

Unbalance compensation capabilities in an unbalanced grid

**TRL:** 3-9

**Total budget required:** 230 m€

**Timeline:** 5 years

| **Parties / Partners** (countries / stakeholders / EU) | **Implementation financing / funding instruments** | **Indicative financing contribution** |
|---|---|---|
| Belgium (Flemish Region) | National/regional funding : Flemish agency "Flanders Innovation & Entrepreneurship" and the Research Foundation Flanders | 1,25 m€/5 years (estimation, since bottom up non thematic funding programmes) |
| Germany | National funding (Federal Ministry of Economics and Energy) and industry resources | 25 m€/5 years |
| Austria | National funding in programme "Energieforschung" (Klima- und Energiefonds) and industry resources | |
| Italy<br>Industrial Partners<br>Engineers, Architects<br>Universities and Research Institutions | Ministry of Economic Development (MISE), Ministry of Education, University, and Research (MIUR), funding from Regions | substantial financing contribution is intended but cannot be specified at present |

| | | |
|---|---|---|
| Sweden | Swedish Energy Agency<br>National R&I funding programme TERMO | Sweden is interested in the activity, but currently cannot provide an indicative level of financial contribution per each AF. |
| Public procurement<br>Industrial partners<br>- EnergyVille/VITO,<br>- HP manufacturer or association,<br>- EEBus initiative,<br>- Ghent University<br>- Inverter manufacturer<br>- Member States<br>- DHC and electricity utilities<br>- Cities<br>- Buildings owners<br>- Consumer organisations<br>- Industry actors and commercial energy providers<br>Italy: Politecnico di Milano, CNR, ENEA<br>France: Boost heat, GDF<br>UK: University of Warwick<br>Germany: Fraunhofer ISE | | |

| **Ongoing R&I Activities (Flagship activities or not): relevant to this new activity proposal** | | | | |
|---|---|---|---|---|
| **Name** | **Description** | **Timeline** | **Location/Party** | **Budget** |
| *H2020 FHP* | Flexible Heat and Power – Connecting distributed heat with power networks by harnessing the complexity in distributed thermal flexibility<br>http://fhp-h2020.eu/ | 11/2016-10/2019 | EU-project<br>Coordinator BE: EnergyVille/VITO | EU contribution 3.8 m€ |
| *PHD-project* | Grid supporting converter<br>https://www.esat.kuleuven.be/electa/research-assistants/00091831 | 2015-2018 | BE | |
| *H2020 MPC-GEOTABS* | Project on combining geotabs with heat pump technology | 2017-2021 | EU-project<br>Coordinator BE: Ghent University | EU contribution 4.0 m€ |
| *RELAB* | Field test monitoring of heat pumps in public buildings | Ended 2015 | Lombardy Region | 1.1 m€ |
| *HEAT4U* | FP7 - Collaborative project<br>Grant Agreement no.285158 | Ended 11/2014 | Participants: Energyville/KULeuven | Total cost 9.1 m€<br>of which EU contr. 6.25 m€ |
| *TheSAn* | Functional demonstration of a thermochemical system for industrial waste heat recovery (high temperature heat pump). The aim of the project is the functional demonstration of a thermochemical system for industrial waste heat recovery regarding cyclability of the reaction materials as well as the operational aspects of this new technolo-gy. An economic feasibility study will be performed that forms the basis for a target-oriented technology development of the respective technologies in follow-up projects. | 06/2015-11/2018 | DE: DLR, Evonic, Siemens, Uni Siegen, Uni Hamburg | 2.1 m€ |

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| *High tempera-ture heat pump* | Development of a high temperature heat pump for temperatures up to 160°C based on a refrigerant cycle with solution cycle | 10/2018-03/2021 | DE: AGO | 1.0 m€ |
| *HEAVEN* | Low exergy concepts for heat supply of existing multi-family buildings: power modulating brine heat pump with multi source system and decentralized ventilation | 01/2018-12/2020 | DE: Viessmann, Fraunhofer | 3.5 m€ |
| *ADOSAN-LXB* | LowEx concepts for heating of existing multi-family homes: Development and Demonstra-tion of a Gas driven Adsorption Heat Pump System for Retrofit of the Building Stock | 08/2018-07/2021 | DE: Fraunhofer, Fahrenheit, KIT, Haugg-Kühlerfabrik, Herrmann, DVGW | 5.6 m€ |

**Gaps**:

- Available heat pump models for the design exploration
- Smart thermostat control algorithms
- Heat pump design for more flexible operation (less restrictions in continuous range of control)
- Standardized interfacing with HEMS/BEMS that can query for capabilities, and provide flexible (direct) control commands

## R&I Activity 5.2-2: Multi-source District Heating integrating renewable and recovered heat sources, higher temperature District Cooling and optimization of building heating system, to minimize the temperature levels in district heating networks

**Strategic Energy Technology Plan**
Action 5.2
Cross Cutting Heating and Cooling Technologies for Buildings

### Implementation Plan – Activity Fiche

**Innovation Target: 2**
District heating and cooling: Increase amount of renewable heat by 25% cost effectively and without decreasing the service provided to consumer; Decrease of the DHC substations reference costs for residential buildings by 20% (compared to 2015 prices).

**Title:** Multi-source District Heating integrating renewable and recovered heat sources, higher temperature District Cooling and optimization of building heating system, to minimize the temperature levels in district heating networks

**Individual Building** ☒ **Neighbourhood/ District** ☒ **Others** ☐

**Activity number**: AF 5.2-T2

**Description:**
Multi-source District Heating integrating renewable and recovered heat sources:

- Develop and implement measures for integrating additional RES and REC heat sources in various sizes of existing DH networks in a cost-efficient manner
- Develop and implement measures specifically targeting the combination of constant and fluctuating sources in general but particularly taking into account specific needs for:
    - Base load supply and competing base load sources
    - Seasonal loads vis-à-vis the seasonal availability of sources
    - Peak loads, peak availability of sources vis-à-vis the investment costs especially compared to current standard gas-fired peak boilers
- Develop suitable models for the efficient usage of close to zero cost electricity via boilers and heat pumps in combination with short and long-term storage solutions
- Develop suitable digital solutions for the operation of complex multi-source networks
- Develop, implement and share business models for multi-source DH networks including hybrid solutions and bidirectional connections.

Higher temperature District Cooling for the integration of more natural cooling and increased efficiency:
District Cooling is an efficient community technology that allows for the integration of a variety of cold sources. By using economies of scale it increases the efficiency of cooling while allowing for the use of multiple recovered and renewable resources. Thanks to its community character it also lowers peak loads in the electricity grid substantially. So far grids run on 6-7°C typically. An increase of this temperature would open new sources and technologies while decreasing loads. To achieve this aim the following steps are necessary:

- Develop and redesign DC distribution and control systems to allow for higher temperatures by limiting necessary flows

- Develop and redesign substations for varied transfer parameters and flows, especially for higher heat transfer capacities
- Develop and redesign secondary systems on the consumer side deviating from a traditional 12°C internal supply temperature to higher secondary temperatures
- Implement and demonstrate the new and redeveloped equipment in various showcases.

Optimization of building heating system, to minimize the temperature levels in district heating networks:
DH Networks traditionally operate with high supply temperatures in order to reduce the investment costs by reaching the required transport capacity with small pipe diameters and using cost effective customer installations. The integration of renewables and waste heat sources requires an adaptation of the temperatures in the DH networks. Whereas new networks can be designed for the temperature level of the local available heat source a priori existing networks require major adaptations. The most important parameter related with the DH network is to minimize the return temperature. Especially in 4GDH network the return temperature should be close to the room temperatures. Reducing the return temperature is quite significant for the DH technology because the mass flow rate and the network distribution losses can be reduced and the generation efficiency can be improved. However, the lower return temperatures in the DH network are depended on the efficient operation and control of the indoor heating system elements of the buildings. The most important element of the indoor heating system are the radiators. The aim of this research and innovation topic is to improve the design and the operation of the building heating system in order to be properly adjusted into the operation conditions of the 4GDH, of lower supply and return temperatures.

- Identify and eliminate possible errors related to the design of the existing heating system to operate under 4GDH
- Improve the control of the operation of the indoor heating system in order to operate under 4GDH principles
- Identify how the heating system can be adapted to the lower energy requirements after the renovation of the existing building in order to operate under 4GDH principles.

**Impact:**
Multi-source District Heating integrating renewable and recovered heat sources:
The activity aims at identifying new solutions compared to the conventional, central production units that are in use today. Feeding multiple heat sources into a system necessitates better control of the system at the same time that it strengthens the resilience of the DH provider (no longer reliant on one, large heat source). Successful usage of multi-source DH will result in phasing out of fossil fuels and reduce the need for primary energy sources. The multiple sources will be renewable or recovered and are thereby fossil free. Optimizing system operation necessitates new competencies which are a possible area to create new, green jobs.

- Increase of the share by specifically targeting base load, seasonal load and peak load operations
- Integrating renewable energy source electricity
- Applying smart digital solutions
- Considering bidirectional connections.

Higher temperature District Cooling for the integration of more natural cooling and increased efficiency:
By increasing the temperatures in District Cooling grids from today's 6-7°C to 12°C a whole range of additional sources for natural cooling would be usable. Auxiliary energy (electricity) that was needed to lower the temperature of natural cooling sources in cases temperature demands of about 6°C were not met are often not needed anymore. Especially in areas where the temperature of natural cooling sources increases in the main cooling period (for example seas cooling in the Mediterranean) higher temperature DC can

- Cut electricity peak demands
- Increase the efficiency of cooling
- Increase the share of natural cooling compared to traditional cooling mechanisms.

On the equipment side an increase in DC temperatures would result in increased efficiencies for cold production in chillers or heat pumps by at least 2% per degree Celsius. The envisaged increase could therefore lead to an efficiency increase of 10%+ resulting in cutting fossil fuel shares respectively. The increase in temperatures also fosters the integration of DC with 4$^{th}$ generation DH as well as with return loops in low temperature DH grids.

Optimization of building heating system, to minimize the temperature levels in district heating networks:

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| • Decrease the return temp. by at least 5°C in significant network sections<br>• Increase the efficiency of the existing supply units by 10% and/or enabling the connection of new renewable heat sources and/or waste heat in an economic manner. | | |
| **Expected deliverables:**<br>Multi-source District Heating integrating renewable and recovered heat sources:<br>• Annual report summarizing the business model development<br>• Overview over load specific solutions<br>• System analyses and simulations<br>• Analysis of the potential to use close to zero cost electricity in 5 existing DH networks in different countries<br>• Realization of an 25% increase using a combination of solutions in 5 existing DH networks in different countries covering different load conditions.<br><br>Higher temperature District Cooling for the integration of more natural cooling and increased efficiency:<br>• Annual report summarizing the technology developments<br>• Technological developments<br>• Overview over design solutions for buildings adjusted to higher flow temperatures<br>• Realization of an 25% increase using a combination of solutions supplying higher temperatures in 5 existing or new DC networks in different countries covering different load conditions.<br><br>Optimization of building heating system, to minimize the temperature levels in district heating networks:<br>• Large scale demonstration of the technical feasibility and economic competitiveness of low temperature grids combining the above described aspects<br>• Demonstration of buildings delivering heat or cold to DHC networks. | | |
| **TRL:** 4-9 | | |
| **Total budget required:** 145 m€ | | |
| **Timeline:** 6 years | | |
| **Parties / Partners**<br>(countries / stakeholders / EU) | **Implementation financing / funding instruments** | **Indicative financing contribution** |
| Belgium | National funding: Flemish agency “Flanders Innovation & Entrepreneurship” and the Research Foundation Flanders | 9.5 m€/5 years (estimation, since bottom up non thematic funding programmes) |
| Germany | National funding (Federal Ministry of Economics and Energy) and industry resources | 30 m€/6 years |
| Austria | National funding: Federal Ministry for Transport, Innovation and Technology via research program “City of Tomorrow” and industry resources | 1 m€/year<br>(still to be confirmed) |
| Sweden | Swedish Energy Agency<br>National R&I funding programme TERMO | Sweden is interested in the activity, but currently cannot provide an indicative level of financial contribution per each AF. |

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| Italy<br>Industrial Partners<br>Engineers, Architects<br>Universities and Research Institutions | Ministry of Economic Development (MISE), Ministry of Education, University, and Research (MIUR), funding from Regions | substantial financing contribution is intended but cannot be specified at present |

**Ongoing R&I Activities (Flagship activities or not): relevant to this new activity proposal**

| **Name** | **Description** | **Timeline** | **Location/Party** | **Budget** |
|---|---|---|---|---|
| *H2020 TEMPO* | Development and implementation of solution package for low temperature DH networks | 2022 | EU-project Coordinator BE: EnergyVille/ VITO | EU contribution 4 m€ |
| *H2020 STORM* | Intelligent control of DHC networks with self-learning algorithms | 2020 | EU-project Coordinator BE: EnergyVille/ VITO | EU contribution 2 m€ |
| *Smart Heat Grid Hamburg-Wilhelmsburg* | The Goal of this project is to develop and test an intelligent district heating system that allows a flexible operation of electric-coupled heat generators and renewable heat generators. Similar to the smart grid in the electrical sector, all actors and processes will be connected by communication technologies. By this, a higher efficiency and a higher flexibility could be achieved. The effects of these concepts will be tested and evaluated by field tests in a district heating system of Hamburg Energie. | 2017-2020 | DE: HAW, Hamburg Energie GmbH, eNeG | 2.2 m€ |
| *EnVisaGe – Communal net based energy supply – Vision 2020 on the example of the Community Wüstenrot* | Realized demonstration sites (Plus energy district, biomass and solar driven heating grid, larger battery in School building) are analyzed to evaluate the efficiency of the technologies installed. Optimization measures in the intelligent control are proposed and implemented. Provide surplus electricity from "urban energy cells" to larger consumers in higher populated areas. New promising heating grid concepts for rural settlements with low building density are developed. Evaluation of innovative investment, shareholder and operator concepts. | 2012-2019 | DE: HfT Stuttgart, Gemeinde Wüstenrot, Liacon, ads-tec, HS München, Stadtwerke Schwäbisch Hall | 4.5 m€ |
| *DELFIN* | Prediction of the effects of decentralized feed-in of heat from renewable energies or other heat generators in district heating systems | 2016-2019 | DE: AGFW, TU Dresden, Solites | 1.4 m€ |
| *Smart thermal Subgrid* | Planning and implementation of innovative sub grids for integration in an overall concept. The subnet is intended to promote the integration of local renewable energies, to be operated in conjunction with the grid for the upstream Mannheim district heating network, to efficiently supply the heterogeneous buildings and to integrate it into the system for more flexibility and intelligence. | 2018-2021 | DE: Fraunhofer IEE, MVV Netze GmbH, Uni Kassel | 1.8 m€ |
| *ecoRegeneration: Development of a "Merit-Order" in order* | In urban residential areas there are not enough active-cooled usages, to use the waste heat of the cooling process as | 2016-2019 | Austria: e7 Energie markt Analyse, Institute of | 0.4 m€ |

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| *to assess regeneration heat for geothermal probes within urban residential neighbourhoods* | required regeneration heat for geothermal probes; free cooling of the apartments is not sufficient. The project is developing various options (waste heat from commercial uses in the ground floor zones of residential buildings, by using waste heat of data centres, additional installation of heat generation systems for regeneration) within the urban settlement area, business models and is calculating life-cycle-costs of all solutions. The result should be a kind of "merit order" for regeneration heat. | | Building Research & Innovation ZT, Urban Innovation Vienna, Vasko & Partner | |
| *TFlex - Temperature-flexibilisation in low-load operation of local district heating systems* | Within the research project TFlex it is planned to check if the losses adherent to small district heating networks during low-load periods can be reduced. One possible solution is by deactivating the network and supplying the customers from previously charged decentralized storages. The optimal clustering of the storages and the possibility of solar-charging the storage will be calculated with the aim of a guaranteed one-hundred percent heat supply. | 2015-2018 | Austria: Montan University Leoben, FH Joanneum, TB Harald Kaufmann | 0.2 m€ |
| *Eco.District.Heat - Potentials and restrictions of grid-bound heating systems of urban areas* | Aim of the project Eco.District.Heat is to provide strategic decision-making support that enables Austrian towns and cities to deal with aspects of grid-bound heating (and cooling) systems in accordance with integrated spatial and energy planning from a holistic perspective when elaborating urban energy concepts. | 2016-2018 | Austria: University of Natural Resources and Life Sciences, Austrian Energy Agency, Resource Management Agency | 0.1 m€ |

## R&I Activity 5.2-3: Cost reduction and increase in efficiency of micro CHP/CCHP

**Strategic Energy Technology Plan**
Action 5.2
Cross Cutting Heating and Cooling Technologies for Buildings

### Implementation Plan – Activity Fiche

**Innovation Target: 3**
Micro CHP/CCHP: Cost reduction for equipment and installation by 50% (compared to 2015 market price); Increase of the energy efficiency of Micro CHP/CCHP by 20% (compared to 2015 levels) by increasing operational electrical efficiency and maintaining thermal efficiency.

**Title:** Cost reduction and increase in efficiency of micro CHP/CCHP

**Individual Building** ☒ **Neighbourhood/ District** ☒ **Others** ☐

**Activity number**: AF 5.2-T3

**Description:**
Development of hybrid technologies aimed to integrate the micro CHP/CCHP with other processes based on renewable energy sources. The research activities would include:

- Biofuel production, integrating exhaust heat into the production of raw material (e.g. in connection with greenhouses, algae growth, etc. where also CO2 could be used);
- Renewable fuel production as power to gas (e.g. start methanisation => thermal integration);
- Integration of different energy sources in micro turbines (e.g. solar, biomass, etc.) => towards the island energy system;
- Hybrid systems (e.g. micro turbines with fuel cells, pellet boiler and Stirling engines, micro turbines or Stirling engines with CSP);
- System integration with other RES technologies;
- Integration of storage solutions.

Development of energy efficient micro CHP/CCHP technologies for single family house requires basic research activities on the following topics:

- Development of new and/or existing cycles;
- Development of high efficient components with a longer lifetime and advanced characteristics in terms of corrosion resistance and clogging/fouling resistance;
- Development of lower/zero emissions combustors;
- Power factor correction; Grid code compliance; connection with energy storage; off grid capability; higher grid micro-interruption resistance.

**Impact:**
Primary energy savings:

- residential and commercial buildings: higher than 50% compared to conventional generation of electricity and heating
- single family houses: 15% compared to conventional[4] generation of electricity and heating.

[4] Electricity produced by centralised power generation plants; heating produced with gas boilers.

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| GHG emissions:<br>• single family houses: 36% $CO_2$ reduction compared to conventional[2] generation of electricity and heating. |
| **Expected deliverables:**<br>• Full integration of renewable energy sources in a micro CHP/CCHP system for residential and commercial buildings and single family houses<br>• Higher electrical efficiency<br>• Higher power to heat ratio<br>• Reduction of maintenance costs of micro CHP/CCHP in residential and commercial buildings<br>• Higher operational flexibility based on demand<br>• Increased components performance at lower temperature<br>• Increased effectiveness of components. |
| **Monitoring mechanism:**<br>Monitoring of the market prices.<br>Monitoring of the primary energy savings and the GHG emissions. |
| **TRL:** 3-8 |
| **Total budget required:** 30 m€ |
| **Timeline:** 36 month |

| **Parties / Partners**<br>(countries / stakeholders / EU) | **Implementation financing / funding instruments** | **Indicative financing contribution** |
|---|---|---|
| Germany | National funding (Federal Ministry of Economics and Energy) and industry resources | 15 m€/3 years |
| Austria | National funding in programme "Energieforschung" (Klima- und Energiefonds) and industry resources | |
| Sweden | Swedish Energy Agency National R&I funding programme TERMO | Sweden is interested in the activity, but currently cannot provide an indicative level of financial contribution per each AF. |
| Italy<br>Industrial Partners<br>Engineers, Architects<br>Universities and Research Institutions | Ministry of Economic Development (MISE), Ministry of Education, University, and Research (MIUR), funding from Regions, funding from Regions | substantial financing contribution is intended but cannot be specified at present |
| micro CHP industry,<br>research institutes,<br>users | Mix of national and EU funding | |

**Ongoing R&I Activities (Flagship activities or not): relevant to this new activity proposal**

| **Name** | **Description** | **Timeline** | **Location/Party** | **Budget** |
|---|---|---|---|---|
| *Bio-HyPP* | Development of a full-scale technology demonstrator of a hybrid power plant with 30 kWe, coupling of Micro Gas Turbine (MGT) and Solid Oxide Fuel cell (SOFC). | 2015-2019 | EU: DLR, MTT, UNIGE, Hiflux, TUe, D'Appolonia, Sunfire | 5.8 m€ |

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| *FlexiFuel-SOFC* | Small-scale fixed-bed updraft gasifier. A compact gas cleaning system and a solid oxide fuel cell. | 2015-2019 | EU: Windhager, Hygear, Bioenergiesysteme, TU Delft, Fraunhofer, AVL, Wuppertal Institute, Universiteit Utrecht | 5.9 m€ |
| *NANOCOGEN+* | Small scale MGT for single household using flameless combustion. | 2015-2019 | Belgium: ULB/VUB, MITIS | 0.5 m€ |
| *WoW (With or Without)* | Development of a highly flexible, carbon clean micro gas turbine. | | Belgium: ULB | |
| *FlexiHAT* | Flexible heat production in combined heat and power using d air turbine. | | Belgium: ULB/VUB, ENGiE | |
| *MGT-mBHKW* | Development of a recuperated Inverted Brayton Cycle micro gas turbine CHP demonstrator for single family houses with 1kWe. | 2015-2018 | Germany: BMWi, EnBW, DLR | 1.2 m€ |
| *HERMiT* | High effectiveness recuperator for micro turbines | | UK | |
| *MiTREC* | Micro turbines renewable energy combustor. | 2017-2019 | UK: Bladon jets, Staffordshire University, Cranfield University and QTE | 1.3 m€ |
| *HiPerTurbines* | High performance micro-turbines for CHP applications | 2015-2017 | Eurostars: TUe, MTT, BBA, RWTH | |
| *ONSITE* | Hybrid SOFC –High temperature battery (Sodium Nickel Chloride) CHP for resilient smart micro grids | 2013-2017 | EU: CNR, HTceramix/SOLIDpower, Ericsson | 5.5 m€ |
| *Fund for the development of the national power grid managed by Ministry of Economic Development (MISE)* | Development of small scale CHP-CCHP | 2018-2019 | Italy: CNR, Universities | 0.6 m€ |

## R&I Activity 5.2-4: Compact thermal energy storage materials, components and systems


**Strategic Energy Technology Plan**
Action 5.2
Cross Cutting Heating and Cooling Technologies for Buildings

### Implementation Plan – Activity Fiche

**Innovation Target 4:**
Thermal Energy Storage: Improve the performance of above ground and underground energy storages (energy efficiency, system lifetime, O&M) by 25% (compared to 2015 levels): Increase of 200% of storage density at the system level (including pumps, valves, pipes, short term buffer) from the current state of the art 60 kWh/$m^3$.

**Title:** Compact thermal energy storage materials, components and systems

**Individual building** ☒ **Neighbourhood/ District** ☐ **Others** ☐

**Activity number**: AF 5.2-T4

**Description:**
Compact thermal energy storage (CTES) systems enable the storage of available renewable electricity for short or intermediate periods in power to heat configurations or of solar thermal energy or PV electricity for seasonal thermal storage, using a minimal amount of space in the building.
Several CTES technologies have reached a TRL 5 to 6. A further improvement towards cost effectiveness of such systems is dependent on the development of novel, cost-effective compact thermal energy storage materials and novel or improved components, integrated and tested in complete storage systems.
For **materials**, novel material classes, like mesoporous materials or composite materials need to be further developed, testing methods need to be developed and assessed and the materials have to be integrated in the reactor components. Cost reduction is an important target for the storage materials development. For the **components**, new reactor principles need to be developed and optimized, and existing heat exchanger designs need to be optimized for the storage materials. On **system** level, the components need to be controlled in an optimal way, with novel sensor technologies to determine the state of charge and control strategies that take the typical characteristics of thermochemical processes into account.
A set of key performance indicators on the three levels will be (further) developed in order to have a basis for the quantification of the development progress.
There are a number of national and international activities ongoing and completed. An international coordination in combination with an effective knowledge exchange would accelerate the development, in combination with an intensification of the R&D activities themselves.

**Impact:**

- 3 to 5 novel (thermochemical) storage materials that have a good cyclic performance for either electric or solar thermal charging. Energy storage density on material bulk level is 180 to 300 kWh/$m^3$ at minimum.
- 3 to 5 novel reactor or heat exchanger designs with proven charging/discharging performance and potential for cost reduction.
- A stepwise improvement of the storage density on system level from the present 60 kWh/$m^3$ towards 250 kWh/$m^3$ for thermochemical materials based systems.

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| **Expected deliverables:**<br>• Novel (thermochemical) storage materials<br>• Designs for reactors and heat exchangers<br>• Compact thermal energy storage systems<br>• Publications in scientific and professional journals; contributions to conferences; project reports.<br>• Evolving energy storage industry with focus on thermal energy storage i.e. start-ups, SME. |
| **Monitoring mechanism:**<br>Annual assessment of the development along a number of key performance indicators, developed in this Activity. Monitoring will be done by funding agency. |
| **TRL:** start at 2 to 6, end with 5 to 7 or 8 |
| **Total budget required:** 200 m€ (based on a fivefold increase of the present budget, needed to establish the critical R&D mass) |
| **Timeline:** first projects in 2019, impact goals for 2025 |
| **Organizations interested in participation:** |

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| AEE INTEC | AT | Danish Technical University | DK |
| VITO | BE | CIC EnergiGune | ES |
| EMPA | CH | University of Lleida | ES |
| HEIG-VD | CH | INSA Lyon | FR |
| HSR SPF | CH | Promes-CNRS | FR |
| Fraunhofer IGB | DE | TNO | NL |
| ITW- TU Stuttgart | DE | TU Eindhoven | NL |
| TU Munich | DE | National Institute of Chemistry | SI |
| University of Leipzig | DE | Cukurova University | TR |
| ZAE Bayern | DE | | |

| **Parties / Partners**<br>(countries / stakeholders / EU) | **Implementation financing / funding instruments** | **Indicative financing contribution** |
|---|---|---|
| Germany | National funding (Federal Ministry of Economics and Energy) and industry resources | 5 m€/year |
| Italy<br>Industrial Partners<br>Engineers, Architects<br>Universities and Research Institutions | Ministry of Economic Development (MISE), Ministry of Education, University, and Research (MIUR), funding from Regions | substantial financing contribution is intended but cannot be specified at present |
| Sweden | Swedish Energy Agency<br>National R&I funding programme TERMO | Sweden is interested in the activity, but currently cannot provide an indicative level of financial contribution per each AF. |
| Austria | National funding in programme “Energieforschung” (Klima- und Energiefonds) and industry resources | |

| Ongoing R&I Activities (Flagship activities or not): relevant to this new activity proposal | | | | |
|---|---|---|---|---|
| **Name** | **Description** | **Timeline** | **Location/Party** | **Budget** |
| *TESSe2b* | An integrated solution for residential building energy storage by solar and geothermal resources | 10/2015-09/2019 | PT, Polytechnic Institute of Setubal | 6.6 m€ |
| *Tes4seT* | Development line A: Development of seasonal solar thermal storage technology using the charge boost principle and a dedicated sorption collector | 10/2014-09/2018 | AT, AEE INTEC | Project: 4.3 m€; CTES development line about 0.8 m€ |
| *UniSto* | Development of a universal modular heat accumulator and its testing as a solar storage in multi-family houses | 06/2013-05/2016 | DE, ITW Univ. Stuttgart | 0.7 m€ |
| *CREATE (Compact retrofit advanced thermal energy storage)* | The objective is to develop a thermo-chemical storage system and demonstrate its functioning under realistic conditions (in an inhabited dwelling in Poland) | 10/2015-09/2019 | NL, TNO, and AT, AEE INTEC | 6 m€ |
| *COMSTES* | Development of standard characterisation techniques for PCM and TCM based heat storages at low (< 100 C) and high (> 100 C) temperatures and database on standard properties | 2017-2019 | NL | 1 m€ |
| *ERP ESC (Early Research Programme Energy Storage and Conversion* | Development of new TCM materials and understanding of their behaviour on system level | 2016-2020 | NL | 0.5 m€ |
| *SCORES* | Demonstration of a Heat and Electric storage unit, with application of heat pumps & electric heaters for conversion from power to heat | 11/2017-10/2021 | NL | 6 m€ |
| *SAMSSA* | Study of sugar alcohol and eutectics as PCM for seasonal storage | 04/2012-03/2015 | FR; CNRS, AIDICO, Fraunhofer, IMNR, EURICE, SOLVAY, CIC Energigune, PCM Product, TU/e | 2.9 m€ |
| *CITYZEN / Flaubert district heating demonstrator in Grenoble* | Development of a PCM storage for a district heating substation, connected to a thermal solar field and a smart management system. | 03/2014-11/2019 | Grenoble / CEA, CCIAG | Project: 25 m€; PCM storage ~0.8 m€ |
| *HYBUILD* | Development, realization and validation of hybrid electric/thermal storage solutions for domestic applications under both Mediterra-nean and Continental climates | 10/2017-09/2021 | ES, COMSA Corporacion | 6 m€ |
| *SWS-HEATING* | Development and validation of a compact seasonal storage for heating demand of single-family houses, based on innovative composite sorbent materials. | 06/2018-05/2022 | GR, National Technical University of Athens | 5 m€ |
| *ABSTOREX* | Absorption storage of thermal energy in aqueous sodium lye | Extension 12/2017 to 06/2020 | CH, SPF | 0.45 m€ |

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| *PCM-Demo II* | PCM in demonstration applications | 06/2015-06/2019 | D, ZAE, Uni Kassel, Fraunhofer, Ing.büro Prof. Dr. Hauser, Deerns, H. M. Heizkörper, Rubitherm, va-Q-tec | 3.7 m€ |
| *DiTes4Grid* | Thermal storage as shiftable loads in the electrical network | 04/2014-03/2018 | D, ZAE, BSH Hausgeräte | 1.8 m€ |
| *IAST* | Industrial waste heat utilization of a foundry by thermal energy storage in combination with an absorption process | 06/2013-11/2018 | D, Gießerei Heunisch, ZAE, Küttner | 2.5 m€ |
| *MoLaSKa* | Latent thermal storage modules (salt PCM) for split logs fire places | 01/2016-12/2018 | D, Wamsler Bioenergy, HS Zittau/Görlitz | 0.3 m€ |
| *PCMEval* | Evaluation of PCM applied in buildings - Long term experiences using PCMs in buildings | 09/2016-06/2019 | D, Fraunhofer | 0.6 m€ |
| *properPCM* | Property prediction and characterization of mixtures for the development of efficient phase change materials in relevant temperature ranges | 12/2015-05/2020 | D, ZAE | 1.3 m€ |
| *SPICE* | Measurement of temperature fields in large hot water storage tanks in CHP based District Heating Systems as a tool to increase efficiency | 05/2015-12/2018 | D, TU Dresden | 0.8 m€ |
| *TESIN* | Thermal energy storage for increasing energy efficiency in heating plants and electric steel plants | 05/2013-01/2020 | D, DLR, STEAG, Badische Stahl-Engineering | 2.4 m€ |
| *KOKAP* | Cost efficient encapsulation of phase change materials | 08/2017-07/2020 | D, Rubitherm, Bischof+Klein, Kramer, Fraunhofer | 2.4 m€ |
| *Latenter Stromspeicher* | Joint Project: Using Latent Heat Storage Units and Heat Pumps for Load Management | 07/2015-01/2019 | D, Fraunhofer, HPS Home Power Solutions, Uni Bochum, Stiebel Eltron | 1.5 m€ |
| *PCM-Screening* | Evaluation of eutectic mixtures for use as PCM: thermodynamic modeling and experimental methods | 12/2016-11/2019 | D, TU Dresden, GTT, FZ Jülich, Uni Cottbus | 1.8 m€ |
| *poMMes* | Synthesis and characterization of porous metal-salt-composites for chemical heat pumps and thermal energy storages | 05/2017-04/2020 | D, TU Dresden, WätaS, Fraunhofer | 1.5 m€ |
| *Speicher-LCA* | The overall objective of this research project is to develop a software tool to give decision-makers a scientifically consolidated assistance for choosing the best thermal energy storage materials and methods with respect to environmental and life-cycle considerations | 10/2015-03/2019 | D, Fraunhofer, ZAE, Uni Stuttgart | 0.9 m€ |

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| *TESS 2.0* | heat storage system for future energy markets 2.0 | 06/2018-10/2020 | D, FH Aachen, Kraftanlagen München, Otto Junker, Dürr Systems | 3.6 m€ |
| **Gaps**: <br>• Presently, there is no established Thermal Energy Storage industry. Special attention should be given to attracting (large) industries to this field. For their participation, an outlook to a steady and growing market for CTES systems should be in place, which needs starting market incentives for the novel systems.<br>• Upfront cost of TES<br>• Lack of energy (electricity, heat) balancing markets and price signals: for an improved value proposition for different TES technologies, time-of-use tariffs and price signals for time shifting would likely be a driver for the uptake of TES<br>• Slow uptake of renewable heating technologies<br>• Large scale seasonal TES: low penetration of district heating and slow uptake of renewable thermal sources<br>• Knowledge and awareness in society, public sector and industry<br>• Underground space constraints and lack of subsurface spatial planning<br>• Stringent planning and monitoring requirements<br>• The use of combi boilers and hot tanks are considered as a proven barrier to PCM deployment<br>• Pre-commercial technology requires demonstration<br>• Size reduction and improved materials needed<br>• Household to housing block sized heat batteries: barriers to prosumerism, reaching autarchy and decentralised solutions. | | | | |

## List of participants

| Country /Association | Name / Organisation | Category |
|---|---|---|
| DE (TWG Chair) | Annett Kühn<br>Rebecca Pannen | National Representative |
| AT | Theodor Zillner<br>Hannes Warmuth | National Representative/ Stakeholder |
| BE | Walloon region: Sara Piccirilli | National Representative |
| BE | Flemish region: Lut Bollen | National Representative |
| BG | Anna Kamburova | National Representative |
| CH | Andreas Eckmanns | National Representative |
| CY | Apostolos Michopoulos | National Representative |
| CY | Lora Nicolaou | National Representative |
| CY | Marina Kyprianou-Drakou | National Representative |
| CZ | Tomáš Smejkal | National Representative |
| CZ | Laciok Aleš | National Representative |
| FR | Brigitte Jacquemont | National Representative |
| FR | Thomas Welsch | National Representative |
| FR | Michel Viktorovitch | National Representative |
| IE | Bob Hanna | National Representative |
| IT | Giuseppe Zummo | National Representative |
| LV | Gunta Šlihta | National Representative |
| LV | Dainis Dravnieks | National Representative |
| NL | Daniel van Rijn | National Representative |
| PT | J. Mariz Graça | National Representative |
| PT | Paulo Martins | National Representative |
| SE | Mehmet Bulut | National Representative |
| SE | Emima Pasic | National Representative |
| TR | Ilknur Yilmaz | National Representative |
| District Heating and Cooling Technology Platform (DHC+)/Euroheat&Power | Ingo Wagner | Stakeholder |
| Energy Materials Industrial Research Initiative (EMIRI) | | Stakeholder |
| European Association for the Promotion of Cogeneration (COGEN Europe), European Turbine Networks | Ugo Simeoni | Stakeholder |
| European Building Automation and Controls Association (eu.bac) | | Stakeholder |
| European Construction Technology Platform - Energy Efficient Building Association | TWG Co Chair: Paul Cartuyvels | Stakeholder |
| European Geothermal Energy Council (EGEC) | Phillippe Dumas | Stakeholder |
| European Heat Pump Association (EHPA) | Vincenzo Belletti | Stakeholder |
| European Platform of Universities in Energy Research and Education (EUA-EPUE) | | Stakeholder |
| European Polyurethane Insulation Industry (PU Europe) | | Stakeholder |
| European Technology and Innovation Platform on Renewable Heating & Cooling (RHC) | TWG Co Chair: W. van Helden | Stakeholder |
| SINTEF Energy Research, Steering Committee of the RHC Biomass panel | Øyvind Skreiberg | Stakeholder |
| Federation of European Heating Ventilation and Air Conditioning Association (REHVA) | | Stakeholder |
| European Solar Thermal Industry Federation (ESTIF) | | Stakeholder |
| EASME | Philippe Moseley | EC Participant |
| EC-ENER | Alexandros Katronoraos | EC Participant |
| EC-ENER | Pietro Menna | EC Participant |
| EC-JRC | Johan Carlsson | EC Participant |
| EC-RTD | Jose Riesgo | EC Participant |
| EC-RTD | Carlos Saraiva-Martins | EC Participant |
| EC SET PLAN | SET Plan Secretariat | EC Participant |