

Climate Neutral Heating and Cooling: RD&D needs and perspectives for international collaboration

Executive Summary Report

On 20 April 2023, a webinar was organized under the auspices of the IEA Experts' Group on R&D Priority-setting and Evaluation (EGRD) in cooperation with Project Management Jülich under the German Federal Ministry for Economic Affairs and Climate Action.

Many governments worldwide have committed themselves to achieve net greenhouse gas neutrality in the next decades in order to limit global warming to well below 2, preferably to 1.5 degree Celsius, compared to pre-industrial levels. In order to reach these goals fossil fuels, which as of today still account for 80 percent of the global total energy consumption will largely have to be replaced by renewable sources. Whereas the decarbonisation of the electricity sector is on a successful path in many countries reaching greenhouse gas neutrality in the heating and cooling sector is much harder. In Germany for example, more than half of final energy consumption is accounted for by heating and cooling, of which so far only a small part has been produced in a climate-neutral way. To decarbonize the heating and cooling sector ambitious initiatives have been launched in many countries in recent years. The recent geopolitical developments, with Russia's aggression against Ukraine and the consequent disruptive developments on the gas market, have furthermore shown the vulnerability of an energy system based on fossil fuels further strengthening governmental efforts to shift towards renewable energy sources in all sectors.

The transformation of the heating sector includes all relevant areas of use and infrastructures. Fossil energy sources must be replaced by renewable energies and the use of waste heat, heating and cooling requirements must be reduced through efficiency measures, and electricity and heating infrastructures must be coupled and used optimally. The heat supply must be converted to a new basis of renewable energy sources, electrification and alternative fuels.

Applied energy research contributes to achieving climate neutrality in the heating sector. Many technical solutions are already available today. However, these are not yet sufficient to reach the target. Research and innovation are necessary to develop further urgently needed technologies and to prepare novel technologies that are not yet established on the market for widespread use. In addition, the systemic integration of new technologies as well as their dissemination and standardisation are still pending. Socio-economic interactions and regional peculiarities must be taken into account.

This webinar focused on RD&D needs in the area of climate neutral heating and cooling in order to serve as an input to governmental research policies and strategies and raised the following key questions:

- What RD&D is crucial to decarbonize the heating and cooling sector?

- Which obstacles hinder the large scale deployment and roll out of climate neutral heating and cooling technologies in various end-use sectors?
- Which problems arise on a system-level?
- How can acceptance problems of climate neutral heating and cooling technologies be overcome?
- Is it possible to shortcut the knowledge creation from basic science to application by means of new methods, technologies and mechanisms?
- How can governments support and accelerate RD&D in climate neutral heating and cooling?
- What are the best opportunities for the IEA TCPs to take forward these research questions?

Key messages from the webinar can be clustered in three statements

Russia's invasion of Ukraine is challenging Europe to accelerate the shift away from imported fossil fuels. Governments are taking measures to reduce dependence and increase energy security while continue to strengthen the commitments to climate neutrality. Climate neutral heating and cooling is an important part of this endeavor.

Statement 1: There is no one size fits all. Room for local adaptation due to the differences in the energy systems is needed.

- The heating and cooling sector is very diverse. Individual solutions need to be found for different regions. This was clearly demonstrated in the MIT study with eight different cities, but also in the Japanese HPTCP presentation.
- The age of the building stock around the world is very diverse. Retrofitting the existing building stock should be of high priority and the renovation rate should be substantially increased.
- There are huge differences when implementing large heat pumps in end-use sectors – households are not comparable to industrial high temperature processes.

Statement 2: There is a substantial need for R&D to unlock the full potential of climate-neutral heating and cooling.

- New technologies need to be developed or existing ones further adapted, e.g.
 - District heating and cooling is a known/mature technology but is constantly under development to be climate neutral and efficient – we are now at the 5th generation district heating and cooling system.
 - Large scale heat pumps and their integration in the system.
 - Lower temperatures in district heating.
 - Use of waste heat from sewage plants and co-generation.
 - Adaptation of cooling and heating systems to ecological refrigerants.
 - Standardization and modularization of the manufacturing process.

- There is a need for R&D in design tools, interactive network modelling at different levels and spaces, guidelines, business models, better tariff structures, incentives and what was termed regulatory learnings.
- Knowledge exchange needs to be strengthened, information campaigns and also reliable certification schemes are needed to facilitate the roll-out of innovative heating and cooling technologies.

Statement 3: International cooperation matters and should be further strengthened.

This is an area where IEA TCPs have cooperated for some years and continue to do so:

- a. EBC – energy in building and communities
- b. DHC – district heating and cooling
- c. ES – Energy storage
- d. HPT – Heat pump technologies

Observation to CERT: Within the technology cooperation framework of the IEA cross-TCP learnings and interaction should be expanded in order to increase the impact of individual R&D efforts.

In the following the individual contributions from the workshop are briefly summarized. For details see the presentation on the workshop webpage: <https://www.iea.org/events/climate-neutral-heating-and-cooling-rd-and-d-needs-and-perspectives-for-international-collaboration>

The workshop was opened by **Wolfgang Langen** from the German Federal Ministry for Economic Affairs and Climate Protection, Head of the Division responsible for Energy Research funding. He stated that decarbonizing the heating and cooling sector is an important step in the German energy transition since more than 50% of Germany's energy consumption is used in the heating and cooling sector. As important topics he mentioned the development and systems integration of heat pumps, a better use of waste heat from processes and the strengthening of geothermal sources for district heating. International cooperation in energy R&D will be important to reach Germany's ambitious goals in the next decade.

Birte Holst Jørgensen, senior researcher at DTU, Copenhagen and Chair of the EGRD gave an introduction to the recent work of the EGRD bringing together experts from R&D, industry and policy making in workshops on cutting edge topics in energy research to provide policy recommendations for energy research.

Session 1 focused on why we have to accelerate climate neutral heating and cooling technologies, the portfolio of technologies to reach the net-zero emission by 2025 and the need for RD&D.

Chiara Delmastro, Energy Analyst Buildings, Energy Technology Policy Division, IEA, gave a presentation on "*Net Zero by 2050: opportunities for innovations in heating and cooling in buildings*". According to the IEA data as of 2021 fossil fuels directly supply over 60% of heat in buildings and many existing buildings worldwide have low energy performances. Many of the

technologies needed to decarbonize the buildings sector are already available, but innovation is needed to adapt products to hard-to-reach market segments and anticipate power sector and infrastructure needs. Innovation at the technology level is essential, in particular in the following three areas: 1) Efficiency improvements in all climates and buildings types, 2) Retrofits, 3) Flexibility and technology/vector coupling. Furthermore, it is important to acknowledge that innovation is not just about technologies but also about design tools, guidelines, training, business models, and awareness campaigns.

Johan Carlsson, Scientific officer, leader of the Sustainable Heating and Cooling team, JRC Petten presented on *“Strengthened EU policies in the heating and cooling domain, and key results from a new heat pump study”*. According to the EU’s *Fit for 55*-Strategy overall GHG-emissions in the EU shall be reduced by at least 55% by 2030. Furthermore with the REPowerEU Plan Europe aims at phasing out the dependence on Russian gas imports. Heat pumps will play an important role to reach these goals. JRC has analysed the opportunities and challenges of a large scale roll-out of heat pumps in Europe in a recent study (published after this workshop took place, available [here](#)). According to this study the large scale deployment of heat pumps in the EU by 2030 would allow to reduce fossil energy consumption by 36%, GHG emissions by 28% and natural gas consumption by 28bcm.

Christoph Reinhart, Professor of Architecture and Climate at MIT, USA, discussed *“Socio-economic carbon reduction pathways for urban building stocks”*. He presented three case studies performed in different neighbourhoods in the US where the willingness of home owners to invest in retrofitting and energetic renovation of their homes and the underlying motivations and drivers were analysed. According to his analysis city governments and policymakers need to better understand the opportunities of existing buildings in their local carbon reduction strategies. He stated that society expects the building sector to deliver carbon neutral new construction for all building typologies by 2030. Heat pumps, PV and (increasingly) batteries are the new default technologies for newly-built residential homes.

Session 2 provided RD&D examples of what is needed for climate neutral heating and cooling. Decarbonising the heating and cooling sector requires substantial RD&D, especially with regards to the integration of different technologies into large-scale systems and their interplay with the electricity system.

Andrej Jentsch, R&D project manager at AGFW, Germany, presented *“R&D needs for large heat pumps and district heating and cooling”*. He shared his experiences from a living lab on large heat pumps for district heating in Germany started in 2021. One of the goals of this living lab is to facilitate the market ramp up of large scale heat pumps in Germany. Concerning district heating and cooling in general a number of R&D needs were identified: The shift from fossil fuels to GHG neutral heat sources in itself bears a lot of uncertainties. The need for flexibility requires various control strategies, variable supply temperatures and the possibility of load shifting amongst others. Other important R&D topics which were identified include digitalization, business models and tariff structures.

Takahide Tokuda, Manager of International Department & Technical Research Department, Heat Pump & Thermal Storage Technology Center of Japan presented an *“Introduction of Japanese district heating and cooling case studies using heat pumps”*. He shared the Japanese experience from several large-scale heat pump projects in different parts of the country (e.g. Tokyo, Osaka) and their learnings: Heat pumps are expected to play a pivotal role in the decarbonisation of the Japanese energy system and are gaining interest as an important urban infrastructure in the thermal energy field.

Martin Patel, Chair for Energy Efficiency, Interim director of the Institute for Environmental Sciences (ISE) at University of Geneva referred on *“SWEET DeCarbCH – Some insights on Decarbonisation of Cooling and Heating in Switzerland ”*. Whereas the electricity sector is mostly carbon-free in Switzerland, the heating sector relies heavily on oil and gas. In the last years heat pumps have become a meaningful alternative to fossil fuels in space heating. Within the DeCarbCH projects different option to decarbonize the heating system in Switzerland have been analysed using a modelling approach as well as in a number of demonstrators.

Session 3 discussed how governments can best support RD&D for climate neutral heating and cooling. Key statements of the discussion are included in the key messages above.