Heating and Cooling Future of Europe and Interactions with Electricity

An IEEE European Public Policy Committee Position Statement

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Recommendations
The IEEE European Public Policy Committee (EPPC), representing a large community of European engineering professionals, believes that the European Union (EU) shall address the critical linkages between electricity generation, its consumption for heating and cooling, the associated carbon emissions and their implications for climate change. The IEEE EPPC welcomes EU research and regulatory efforts aimed at developing optimal sustainable heating and cooling strategies compatible with the development and expanded use of renewable energy sources, including efforts to:

1. Perform integrated energy assessment of heating and cooling technologies and options, in conjunction with electricity generation, to truly quantify system-wide techno-economic and environmental/climate benefits and implications.
2. Perform the above analyses considering costs and benefits at both the power system level and the local network level, as there may be optimal trade-off between the two levels, which might change the feasibility of district energy system schemes, as well as the use of renewable energy sources for heating and cooling including the use of waste heat, and coupling of heating/cooling with electricity both on the generation side (e.g., cogeneration) and on consumption side (e.g., heat pumps).
3. Boost further research to assess integrated options that are available to provide operational flexibility benefits, particularly in the presence of combined heating and power, electric heat pumps, district energy systems and other multi-generation schemes, and better quantify the system-wide benefits that can be provided.
4. Recognize the key role of different types of thermal energy storage in providing benefits and operational flexibility in the heating, cooling, and electricity domains, and investigate the coordination and integration between electricity and heat storage.
5. Favor the development of new business models and new actors, such as flexibility aggregators, which can exploit and bring the integrated energy system flexibility to market.
6. Boost energy policy and regulation measures that consider integrated assessment of the heating/cooling sectors along with electricity.
7. Link future trends and demand scenarios to climate change and to local weather phenomena.
8. Understand heating and cooling as related to normative, behavioural, and architectural questions.
Background

About 50%\(^1\) of the final energy consumption in Europe is used for heating and cooling, of which 80% is used in buildings and 20% for heating in industrial processes. In 2022, 77% of this supply came from fossil fuels and only 23% from renewable sources\(^2\), which resulted in the heating sector alone causing about 38% of the overall European Union (EU) emissions. Whereas heating has long been a major factor in the share of energy consumption, in the last decade cooling has become increasingly important as well, creating challenges for the electricity grid. Therefore, addressing the heating and cooling sectors is key to achieving the European climate goals, as well as increasing concerns with regards to security of supply.

The energy system of the future will exhibit more and more interactions among different forms of energy (“energy vectors”) and various sectors, and in particular, sector integration among heating/cooling and electricity. This is even more evident in urban areas, where most of these interactions take place and exhibit the largest share of heating and cooling consumption. Therefore, it is important for energy planners and policy makers to keep this concept in their minds to reap the benefits of sector integration.

While there are several challenges that Europe will face regarding the future of heating and cooling, there are also opportunities that may arise by optimally deploying innovative technologies and sector integration. This could be done by looking at the tight interactions going on between electricity and heating/cooling from a multi-energy system perspective, and considering setting up low carbon district energy systems, amongst others.

Electricity today is increasingly generated from renewable sources with 40,7% of the power mix in Europe covered by renewables in 2021\(^3\). The use of renewables for direct production of heating and cooling (RES-H&C), such as those based on solar thermal energy, remains limited. In most EU Member States, there is not yet a comprehensive approach to support RES-H&C. As a result, growth in this sector has been sluggish compared to that of renewable electricity. One of the barriers is a lack of awareness among citizens and in the building sector. However, renewable heating and cooling is often already economical today\(^4\), as the payback times are considerably shorter than the lifetime of the technology. If combined with energy efficiency measures to optimize consumption in buildings, RES-H&C could make EU countries less dependent on imports and significantly contribute to the EU’s climate change and security of supply objectives. For example, the Impact Assessment\(^5\) of the European Union Climate Target Plan\(^6\) projects that RES-H&C could reach a share of up to 42% of total EU heating and cooling energy consumption by 2030.

In summary, an energy efficient and sustainable heating and cooling sector with sector integration to electricity (including both cogeneration and heat pumps) has the potential to boost security of energy supply, reduce energy bills, help protect the climate through decarbonization, support the integration of renewable energy sources, democratize energy, reduce emissions on a local level, and free up money spent on fuel imports.

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5. https://eur-lex.europa.eu/resource.html?uri=cellar:749e04bb-f8c5-11ea-991b-01aa75ed71a1.0001.02/DOC_1&format=PDF
Energy Efficiency and Renewables Options for Heating and Cooling

As mentioned in the 2020 EU Strategy for Energy System Integration⁷, “Applying the energy-efficiency-first principle across sectoral policies is at the core of system integration. Energy efficiency reduces the overall investment needs and costs associated with energy production, infrastructure, and use.” Energy efficiency measures range from reducing the need for heating cooling through better insulation and design of buildings, to equipment, like building automated control systems, optimizing the use of heating and cooling, and to more energy efficient production of heating and cooling. These different elements interact and support each other – for instance, a building automation control system may facilitate the interaction between heating/cooling and electricity and thereby facilitate demand side management.

Today, heating has not changed much from the legacy of having largely been generated in fuel-powered boilers, with the type of fuel being determined by regional and country resources, market conditions, country taxation strategies, and so forth. Typical fuels range from natural gas to heating oil, diesel, and biomass. In fact, from an environmental perspective, even natural gas still emits substantial amounts of CO₂, and boilers are an inefficient way to generate low temperature heat compared to electrical heat pumps. Furthermore, from a security of supply perspective, there is always uncertainty as to the real level of available fuel resources, and political issues are raising increased concerns about being energy dependent on other countries and supply lines.

Technically, there are more efficient ways to generate heat relative to boilers. One example is a combined heat and power (CHP) plant where fuel is burned to produce heat in combination with electricity. A mature technology with very high efficiency levels, CHPs can save primary energy (with respect to the separate production of heat and electricity) and help to reduce CO₂ emissions. There are different scales for CHP, from micro-CHP (household level) to city scale (as in some Scandinavian cities). In the latter case, a district energy network is the enabler for technology deployment.

Electric heat pumps will play a pivotal role in decarbonizing the heating and cooling sector. In an electric heat pump, “free” heat is taken from the environment (e.g., air, ground, water) and moved inside the building. While electric heat pumps are mostly deployed at house- and building level scales, they are also available in larger scales to supply a new generation of district heating networks. In addition, they may also provide passive cooling. Other solutions that are becoming widespread include solar thermal energy and geothermal energy, particularly to produce hot water. Both installations can be coupled to local heat pumps to increase efficiency as well. Another source of energy is waste heat from e.g., industries, data centers or supermarkets. When it is possible to connect such waste heat producers to a district energy network, it can be used for heating and cooling of buildings. The H2020 ReUseHeat⁸ project estimated in 2022 that approximately 340TWh of heat could be recovered annually from “unconventional” excess heat sources, such as data centers, metro stations, service sector buildings and wastewater treatment plants. This corresponds to more than 10% of the EU’s total demand for heat and hot water.

Cooling demand⁹ includes heating, ventilation, and air conditioning (HVAC) for houses and buildings, with possibly some district-cooling scheme, particularly for commercial areas and blocks of flats. In warm climates, this results in high demand on summer days, occasionally resulting in grid failures. Of course, sufficient electric power from renewable energy sources could reduce the GHG footprint of such cooling. Alternative technological

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⁸ https://www.reuseheat.eu/
options that do not use electricity inputs also exist, although they are not widespread. These options, for instance, are supplied by fuel (“engine driven chillers”), or thermal energy (“absorption and adsorption chillers”). This thermal energy could come from thermal solar, biomasses, geothermal sources, or waste heat from industry processes. More advanced schemes, adopted in integrated energy supply for buildings or districts, include the so-called trigeneration, whereby some heat produced in CHP plants is used to supply absorption chillers for cooling production. In several cases, these schemes can prove to be highly efficient and economically viable, as in hospitals, commercial buildings, office blocks, etc., when multiple forms of energy may be required for most of the year. In many buildings, however, (passive) cooling via heat pumps will be the most economical way of meeting the cooling demand.

District energy systems

District energy systems have been set up in many cases for heating and/or cooling in urban areas, whereby fuel switching may be a practical option. Based on highly efficient processes and more fuel options, modern district heating systems are, on average, at least twice as clean as conventional heating systems. To facilitate sector integration and their role in it, district energy systems are undergoing a transformation to so-called fourth generation district heating (4GDH) or “smart district heating”. 4GDH networks run on lower temperatures (40-60°C compared to more traditional networks running on 70-130°C), which means more efficient heat source operation, increased range of low-temperature energy sources, and lower distribution losses. With their advanced control functionalities, they are perfectly fitted for the job of connecting different parts of the energy system – electricity, heating, cooling, industry – and using different energy sources flexibly. 4G district energy systems provide the opportunity to integrate waste heat as an energy source and large-scale heat pumps, facilitating the integration with the electricity sector.

In this context, digitalization brings interesting opportunities for gathering and evaluating data, which can be used to improve the accuracy of energy consumption prediction and modeling of building thermal behavior, to optimize temperatures, shift loads by utilizing the building thermal mass as well as utilizing the storage capacities of the district energy infrastructure.

Sector integration – Interaction with Electricity

As mentioned above, in many cases for future options of heating/cooling, the interaction with electricity is key, both in terms of system operation and infrastructure impacts, as well as in terms of environmental benefits. More specifically, for a CHP, the heat requirements will drive electricity production, which may have a positive or negative impact on the local electricity network due to its operational limits. Similarly, the heat requirements in electric heat pumps drive electricity consumption. This can cause local distribution network stress, implying the need for infrastructure reinforcements, advanced control strategies and local electricity network congestion signals. In the case of cooling, it is well known that heating, ventilation, and air conditioning (HVAC) devices have already been the cause of major electricity consumption peaks and disruptions in the electrical systems in several countries worldwide.

Thermal energy storage, including both heat and cooling storage, could, in all cases, provide significant benefits to decrease potentially negative impacts and maximize economic and environmental benefits. An example is the so-called “duck curve”\(^{11}\), arising in the power systems with expanding solar power production, which shows over the course of a day the temporal mismatch between peak electricity demand and renewable energy production. For instance, HVAC electricity peak consumption can be shifted to off-peak times to decrease network impact if thermal storage is available, which may flatten the central part of the duck curve and bring economic benefits. Similarly, heat storage can be used jointly with CHP to decouple electricity- and heat production from the demand, potentially relieving electricity infrastructure as well as bringing about other economic benefits, as injection of electricity can be price-driven to maximize power system benefits. The flexibility available from the optimized operation of electricity and heating/cooling systems is a topic that is increasingly gaining attention.

As a further point, from an environmental perspective, the benefits (system-level primary energy saving and CO\(_2\) emission reduction) brought by different heating/cooling technologies are profoundly connected to the electricity system. Decarbonizing the electricity sector clearly paves the way to electrification as a sustainable path for heating/cooling decarbonization, although the associated infrastructure costs need to be accounted for.

Again, in all cases energy storage can bring significant benefits. In addition to the increased flexibility brought by storage elements such as batteries (e.g., in electric vehicles), in systems which are more dominated by variable renewable sources, electric heat pumps can be used to harness clean electricity at times of higher renewable production (which should also coincide with times of cheaper electricity prices) to generate heat, which can be stored as thermal energy if there is insufficient heat demand at the time (e.g., as latent heat or in adiabatic storages with little stand-by losses and high conversion efficiency). On the other hand, a CHP could be powered down if energy storage could, in the meantime, be used to supply local heat demand. Similar applications could be provided by cooling storage with HVAC and trigeneration.

It is therefore clear that by such a smart control of integrated electricity, heat, and cooling resources, it is possible to simultaneously pursue several objectives such as energy saving, GHG emission reduction, increase in security of supply, economic savings, and finally, customer well-being. It is also important to highlight that such an optimal system integration might be facilitated by the presence of district energy systems, including district heating and cooling networks. The feasibility of such schemes usually depends on multiple conditions, but when carrying out the relevant cost-benefit analysis, these benefits should be internalized in the assessment.

**Limitations**

The demand for heating and cooling is furthermore dependent on several other factors, in addition to the technological and economic factors discussed above. The spatial density of the energy demand, caused by varying population density or by individual styles of living, is a well-known impact factor. Large and dense cities produce waste- or ambient heat, leading to the so-called “urban heat island” (UHI), which reduces the relative heat demand in winter, but increases the cooling demand in summer. Depending on the prevalence of heating or cooling days, this results in net positive or negative side effects.

The cultural component of customers dealing with deviations of the preferred or optimal ambient temperature (indoor and outdoor) will lead to a higher energy demand due to the availability of energy efficient technologies. Behavioral change would mean that people switch on air-conditioning rather than dressing up more casually. Passive architectural design on building and district scales can furthermore help reduce the a priori demand for forced heating and cooling by providing optimized shading, ventilation, or harnessing the sun during winter months. The link between building morphology, the end user or occupant, and technology requires complex, interdisciplinary solutions that cannot be reduced to a technological challenge alone.

This statement was developed by the IEEE European Public Policy Committee (EPPC) Working Group on Energy and represents the considered judgment of a broad group of European IEEE members with expertise in the subject field. IEEE has nearly 60,000 members in Europe. The positions taken in this statement do not necessarily reflect the views of IEEE or its other organizational units.

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