Heating and Cooling Future of Europe and Interactions with Electricity

**An IEEE European Public Policy Initiative
Position Statement**

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The IEEE-European Public Policy Initiative believes that the European Union should advance strategies to address the critical linkages between electrical generation, the consumption of electricity for heating and cooling and associated carbon-emissions and their implications for climate change. In particular, we support EU research and/or regulatory efforts designed to develop optimal sustainable heating and cooling strategies compatible with the development and expanded use of renewable electrical generation sources, including efforts to:

- Perform integrated energy assessment of heating and cooling technologies and options in conjunction with electricity generation, to truly quantify techno-economic and environmental benefits and implications in a whole-system fashion
- Perform the above analyses, taking into account costs and benefits at both the system level and the local network level (there may optimal trade-off between the two levels, which might change the feasibility of district energy system schemes) and use of renewable energy sources for heating and cooling
- Boost further research to assess integrated options that are available to provide flexibility benefits, particularly in the presence of combined heating and power, electric heat pumps, and various multi-generation schemes, and better quantify the whole-system benefits that can be provided
- Recognise the key role of different types of thermal energy storage in providing benefits and flexibility in both heating/cooling, as well as electricity domains, and investigate the coordination and integration between electricity and heat storage
- Favour the development of new commercial solutions and actors, such as aggregators, that are capable to exploit integrated energy system flexibility
- Boost energy policy and regulation measures that consider integrated assessment of the heating/cooling sectors along with electricity
- Link future trends and demand scenarios to climate change and to local weather phenomena
- 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 the heating needs of buildings, domestic hot water production, and heating in industrial processes. In addition, much of this supply comes from fossil fuels, meaning significant greenhouse gas emissions, as the heating sector alone causes about 38% of the overall European Union (EU) emissions. Besides heating, in the last decade cooling has become a major factor in the share of energy consumption as well, creating challenges for the electricity grid. Therefore, addressing the heating and cooling sectors is key to achieving the European climate goals[2], 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 sectors, and in particular, 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. Nevertheless, energy planners and policy makers do sometimes not catch this concept, which often considers heating and cooling decoupled from the electrical sector.

On the above premise, while there are a number of challenges that Europe will face regarding the future of heating and cooling, there are also opportunities that may arise by optimally deploying new technologies. This could be done by looking at the tight interactions going on between electricity and heating/cooling in a multi-energy system perspective, and in light of setting up low carbon district energy systems, amongst others.

Electricity today is increasingly generated from renewable sources. Renewables for heating and cooling (RES-H&C), such as those based on solar thermal energy, have largely been neglected. 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 rather sluggish compared to renewable electricity. One of the barriers are a lack of awareness among citizens and in the building sector. However, renewable heating and cooling is often already economical[3] today, 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 European Renewable Energy Council (EREC) projects[4] that RES-H&C could reach a share of almost 30% of total heat consumption by 2020 and cover more than half of the EU´s heat demand by 2030.

In summary, an energy efficient and sustainable heating and cooling sector has the potential to boost security of energy supply, reduce energy bills, help protect the climate, support the

[1] https://ec.europa.eu/energy/en/topics/energy-efficiency/heating-and-cooling
[2] http://ec.europa.eu/clima/policies/strategies/index_en.htm
[3] http://www.sciencedirect.com/science/article/pii/S0038092X15002674and http://www.sciencedirect.com/science/article/pii/S0378778815300074
[4] http://www.eufores.org/fileadmin/eufores/Projects/REPAP_2020/EREC-roadmap-V4.pdf

integration of renewable energy sources, democratize energy and reduce emissions on a local level, and free up money spent on fuel imports.

Current and Future Heating and Cooling Challenges and Options

Today, heating has not changed much from the legacy of having largely been generated in fuel 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 oil, diesel and biomasses. District energy systems have also been set up in many cases, whereby fuel switching may be a practical option. Based on highly efficient processes and more fuel options, modern district heating[5] systems are, on average, at least twice as clean as conventional heating systems.

There are more and more debates as to how to improve the heating sector in many countries where fuels are major inputs. In fact, from an environmental perspective, even natural gas still emits substantial amount of CO_2, and boilers are a relatively inefficient way to generate low temperature heat due to the waste of potentially productive energy (exergy). 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 more and more 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 when fuel is burned in combined heat and power (CHP) plants 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 CO_2 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-heating network with typical supply temperatures, ranging from 70°C to 130°C, is the enabler for technology deployment.

A variety of clean and energy-efficient electro-technologies, such as heat pumps, can play a key role. In an electric heat pump, "free" heat is taken from outside (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 new generation district heating networks. Other solutions that are becoming widespread include solar thermal energy and geothermal energy, particularly for the production of hot water. Both installations can be coupled to local heat pumps to increase the efficiency as well.

Cooling demand[6] can be seen in energy statistics as electricity consumption for refrigeration, air conditioners, large chillers, etc. The latter include 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

[5] http://www.sciencedirect.com/science/article/pii/S030626191100242X, http://www.sciencedirect.com/science/article/pii/S1359431104001243, and http://www.sciencedirect.com/science/article/pii/S0360544214002369

[6] http://www.rhc-platform.org/fileadmin/Publications/RHC_BROCHURE_140311_web.pdf

days, occasionally resulting in grid failures. Of course, sufficient electric power from renewable energy sources could make such cooling cleaner. Alternative technological 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 use 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 in most of the year.

Low Carbon Heating/Cooling and 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 the limits of the infrastructure. Similarly, the heat requirements in electric heat pumps drive electricity consumption. This can cause local network stress, implying the need for infrastructure reinforcements. In the case of cooling, it is well known that heating, ventilation and air conditioning (HVAC) devices have already been the cause of major 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 maximise economic and environmental benefits. For instance, heat pumps and HVAC electricity peak consumption can be shifted to off-peak times to decrease network impact if thermal storage is available, which may also bring economic benefits. Similarly, heat storage can be used jointly with CHP to decouple electricity and heat production from the demand, with potential positive impact on infrastructure requirements as well as economic benefits, as injection of electricity can be price-driven to maximise system benefits. The flexibility available from the optimised operation of electricity and heating/cooling systems is a topic that is quickly gaining attention, although broadly unexplored.

As a further point, from an environmental perspective, the benefits (mainly, system primary energy saving and CO_2 emission reduction) brought by different heating/cooling technologies are profoundly connected to the electricity system. The less efficient and carbon intensive the power system, the more cogeneration and trigeneration production (which exploits high efficiency combined generation) can bring benefits relative to electric alternatives. At the same time, decarbonisation of electricity clearly paves the way to electrification as a sustainable path for heating/cooling decarbonisation, although the associated infrastructure costs need to be accounted for. Again, in all cases there are great benefits that energy storage can bring. In systems which are more and 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 not sufficient 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, CHP could be powered down to allow additional renewable generation 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 how, by such a smart measurement and management of integrated electricity, heat and cooling resources, it is possible to pursue simultaneous objectives such as energy saving, emission reduction, increase in security of supply, economic savings, and last but not least, 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, the aforementioned benefits should be internalised in the assessment. How to do this optimally is the current objective of research to inform policy and regulation[7].

Limitations

The demand for heating and cooling is furthermore depending on several other factors, next to the technological and economic factors discussed above. The spatial density of the energy demand, caused by more or less dense population or from individual styles of living, is a well-known contribution. Large and dense cities produce waste or ambient heat (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 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 efficient technologies[8]. Behavioural change would mean that people switch on air-conditioning rather than dressing-up more casual. Passive architectural design on building and district scales can furthermore help reduce the a priori demand for artificial heating and cooling by providing optimized shading, ventilation, or harnessing the sun during winter month. The link between building morphology, the end user or occupant, and the technology, can consequently not been reduced to a technological challenge alone.

This statement was developed by the IEEE European Public Policy Initiative and represents the considered judgment of a broad group of European IEEE members with expertise in the subject

[7] https://ec.europa.eu/easme/sites/easme-site/files/list-h-c_h2020_-alls_2014-2015_projects.pdf
[8] http://www.toolsofchange.com/fr/case-studies/detail/662/

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