THE ROLE OF ELECTRICITY IN HEATING & COOLING

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Summary

There are strong opportunities to better marry the EU's electricity and thermal energy markets to help drive up penetration of renewables, increase efficiency, lower emissions and support economic growth. Integral to this will be the promotion of efficient electrothermal technologies.

Reaching an optimal balance between various sustainability strategies for the heating and cooling of buildings can be left to market forces, as long as the market conditions for participation are clearly set by regulators. The economic evaluation should be based on the principle of life-cycle costing. The primary energy factor should be correctly calculated and regularly revised, bearing all policy objectives in mind. (**Paper I Issue 1**)

We see no technical limitations to substitute fossil fuels with alternative energy sources in industry, with the exception of those technologies where the fossil fuel is needed for the reaction. Indeed, the promotion of electrothermal processes powered through (remote) renewable electricity has a high potential to improve the environmental performance of industrial heating, increase productivity and efficiency. There are however economic limitations, and thus the solution favoured by the market will depend on the benefit-cost trade-offs, as influenced by the regulatory regime, electricity market design and customer awareness of the range of solutions. (**Paper II Issue 4**)

About ECI

The European Copper Institute supports the concept, stated on several recent occasions by EU Commissioners, of Energy Efficiency First being a fundamental principle within the Energy Union framework and that Member States be encouraged to give energy efficiency primary consideration in their policies.

Despite offering significant potential for improved efficiency, policies covering the provision of heat for industrial and other business processes, along with most forms of heating & cooling, are limited.

In order to develop an effective strategy, the EU needs to adopt a holistic approach in which the cost effective savings potentials from contributing sectors are assessed, alongside a mapping of the current state of the production and consumption of heat, heating & cooling across the Member States.

ECI therefore advocates that Energy Efficiency First is also the core principle behind this initiative.

Electrothermal processing technology is currently available and used for about 10% of process heating applications and represents an area of substantial expertise in the European Union. The Commission and Member States should consider establishing a competence network between academia and industry to enable rapid feasibility assessments and process development for new applications. (**Paper III Issue 3**)

There are economic limitations to the use of electrothermal process technology, and thus the solution favoured by the market will depend on the benefit-cost trade-offs, as influenced by the regulatory regime, electricity market design and customer awareness. A progressive switch to these technologies could very well be promoted in the context of increasing penetration of renewable energies in the electricity generation mix. Suitable market design is needed for the adoption of the full potential of electrothermal applications to provide flexibility services to the electricity system. (**Paper III Issue 4**)

The principal heating and cooling markets are in buildings, as are the major electrical markets, thus buildings are a key domain where linkages between the two markets should be fostered. There are two principal mechanisms for doing this: 1. Fostering the adoption of appropriate electro-heating and cooling applications such as heat pumps and 2. Exploiting the potential for more sophisticated electrically powered control, sensor and feedback systems to inform, manage and optimise the heating and cooling energy systems. Building energy management systems and automation technology offer the prospect of much better control of heating and cooling systems and the elimination of energy wastage within them. At the same time they can facilitate

the integration of electro-thermal storage in the building sector. Given current market imperfections, development of a coherent policy and programmatic framework will be required to drive this forward; however, the value proposition is compelling from a societal and end-user perspective and hence fully merits the effort.

For industry, there is a huge opportunity to link heating & cooling processes with the electricity system. To realise this opportunity requires the development of innovative business models and regulatory upgrades to position industry as a major electricity market participant. Clearing the way to enable these business models to thrive extensively throughout Europe would allow the full DSM potential in industry to be unlocked, thereby making a solid link between the heating & cooling and electricity sectors and supporting higher penetration rates of renewable energy in the electricity system. (**Paper IV Issue 1**)

INTRODUCTION

ECI welcomes the consultation for a heating and cooling strategy for the European Union which represents great opportunities to support the EU's energy and climate goals. We believe it comes at the right moment.

The high end-use efficiency of electricity in combination with the ongoing decarbonisation of the electricity system provides opportunities in the heating sector. A deeper linkage of the markets for heat and electricity enables deeper integration of variable renewables, while avoiding loss-inducing energy conversions and costly electricity storage systems[1].

In this paper, we focus on increasing the linkages between the overlapping markets for heat and electricity. Promoting these provides an opportunity to harness the inherent qualities of these two energy carriers. Both can be produced in a wide variety of ways, but heat is readily stored, in large quantities over prolonged periods of time, whereas electricity can be transported over long distances with relatively low losses (but is relatively difficult to store). As a result, national, regional and eventually even pan-European markets for electricity can be envisioned, supported by heat markets at the local level.

Our comments are provided below for the themes relevant on the role of electricity as introduced in the five issue papers the Commission presented at the EU Heating and Cooling Strategy Consultation Forum to be held in Brussels on 9 September 2015[2].

[1] Sub-optimum integration of the markets of heat and electricity will lead to a larger need for costly alternative flexibility options, such as power-to-gas/hydrogen-to-power conversions and electricity storage, which introduce additional losses in energy systems.

[2] http://ec.europa.eu/smart-regulation/roadmaps/docs/2015_ener_026_heating_cooling_strategy_en.pdf

ISSUE PAPER I - DECARBONIZATION OF HEATING AND COOLING USE IN BUILDINGS

ISSUE 1

"What are the trade-offs between and how can we assess the cost-optimal balance of

1. *measures to reduce energy consumption in buildings;*
2. *on-building renewable energy;*
3. *remote low carbon electricity;*
4. *waste heat and renewable energy based district heating and cooling"*

Cost-optimality needs to be determined on a life-cycle costing basis. With the many climate conditions, building types, heating systems and heating fuels available in the EU, trade-offs between various decarbonisation approaches will be difficult to assess objectively. Instead, we propose to define the conditions for which each of the four approaches set out under this issue could be considered, and let the market decide between them. For example:

- The use of remote low-carbon electricity should be based on a credible and solid certification of electricity production, combined with periodic verification of the supply contract.
- The use of waste heat requires strict sorting of municipal waste.

We welcome option 3 in buildings, which enables the use of larger-scale, and hence more cost-effective renewables for buildings, while addressing space-constraints in urban and suburban environments.

W.r.t. the use of low-carbon electricity in buildings, the issue of the primary energy factor for electricity should be carefully considered, particularly for renewable electricity. The use of a standard factor of 2.5 in this case appears inappropriate and specific factors should be considered that bear policy objectives in mind[3].

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[3]

http://www.leonardo-energy.org/white-paper/high-primary-energy-factor-jeopardizes-renewable-development - shows inconsistencies in PEF calculation; advocates correct calculation & regular revision.

http://www.leonardo-energy.org/white-paper/primary-energy-demand-renewable-energy-carriers-part-1-definitions-accounting-methods - defines various objective methods to calculate PEFs for various renewable energy sources.

http://www.leonardo-energy.org/white-paper/primary-energy-demand-renewable-energy-carriers-part-2-policy-implications - evaluates the impact of PEF calculation methods for renewables on the EU renewable and energy efficiency targets as well as on energy statistics.

ISSUE PAPER II - HEATING AND COOLING USE IN INDUSTRY AND THE TERTIARY SECTOR

ISSUE 4

"Are there technical limitations to substitute fossil fuels with alternative energy sources in heating and cooling supply in industry? Are there environmental and economic limitations?"

As an alternative energy source, we would like to introduce electrothermal processes based on remote renewable electricity as a high potential technology for improving the environmental performance of industrial heating. This is because of the following reasons:

1. Electrothermal technologies can be **highly efficient**, since they generate the heat directly inside the target material as opposed to other technologies that heat material from the outside, which allows greater heating precision and less losses and thus can be the most energy efficient solution overall depending on the application.
2. Electricity is increasingly generated from **renewable energy sources** instead of fossil fuel.
3. In many cases, electrothermal technology can also improve **the cost and/or process efficiency** of the system.

The following list are the most common electrothermal technologies currently in use.

- Resistance heating
  a) Direct: An electrical current is driven through the material to be heated. The material heats up due its electrical resistivity. This is called the Joule effect.
  b) Indirect: An electrical current is driven through a resistance, which heats up through the Joule effect. Through convection and radiation, this hot resistance will heat up a surrounding fluid or gas.
- Infrared heating: A heat source at high temperature emits infrared waves that are subsequently absorbed by a colder object. The heat is transferred by electromagnetic radiation, without the aid of any intermediary, i.e. it also works in a vacuum. The radiation of the sun is a good example of infrared heat.
- Induction heating: A solenoid is used to generate an alternating magnetic flux. If a conductor is placed inside this field, alternating electric currents are induced in this conductor that opposes the alternating magnetic field. These are called eddy currents. The eddy currents heat up the conductor through the Joule effect.
- Dielectric heating: Electrical non-conducting materials (dielectrics) can be dielectrically heated if they have a bipolar molecular structure. When a changing electrical field is created, such molecules will continuously flip-flop as they attempt to align with this field. When the alignment lags the change in orientation of the electrical field, a kind of hysteresis effect is created, which at well-defined frequencies leads to internal heat development.
- Microwave heating: Dielectric heating at well-defined frequencies selected in the 900 - 3000 MHz range.
- Radiofrequency heating: Dielectric heating at well-defined frequencies selected in the 10 - 40 MHz range.
- Electric arc heating: This is typically used to melt metal scrap. The scrap is placed under 1 or 3 graphite electrodes. The electrodes are charged and an electric arc is generated between each electrode and the metal scrap. The high currents through the arc lead to arc temperatures up to 8000 °C. The high temperature gaz jets of the arc heat the metal by convection and by radiation.
- Plasma arc heating: A special type of electric arc heating, using plasma torches instead of graphite electrodes.
- Electron-beam heating: This technique employs a hot cathode at high voltage to beam electrons to the target material.

There is no technical constraint to substitute fossil-fuel with electrothermal technologies (with the exception of those technologies where the fossil fuel is needed for a chemical reaction). From an environmental perspective, such substitution would be highly beneficial. As stated above, it would produce many productivity benefits. The **main barrier is economic**. With a price factor of four between the industrial prices for gas and electricity, the use of electrothermal processes remains currently limited to about 10% of process heating applications. Electricity tends to be used in smaller-scale innovative batch processes with high value-added but can also be beneficial in continuous processes of mass production.

According to a UIE study[4], the full application of the electrothermal potential in industry, in combination with a full decarbonisation of the electricity system, could save over 5.4 billion tons of CO_2 emissions cumulatively by 2050, while improving productivity and value-added of industry.

[4] Egbert Baake, The Scope for Electricity & Carbon Saving in the EU through the use of EPM Technologies, January 2013

ISSUE PAPER III - TECHNOLOGICAL INNOVATION AND UPTAKE OF TECHNOLOGIES

ISSUE 3

"How can the deployment of energy efficient and renewables heating and cooling technologies in industry be facilitated?"

The use of electrothermal processes in manufacturing leads to lean, innovative and high value-added processes. There are a variety of electrothermal processes and applications available (described above). Extending the application of electrothermal technology to other industrial areas requires a feasibility assessment followed by process development.

The Commission and Member States should consider establishing a competence network on electrothermal processing technologies that provides a bridge between academia and industry and can offer such feasibility assessments instantly. Substantial expertise in this field can be found in the universities of Bayreuth, Cartagena, Hannover, Leuven, Lodz, Modena, Nantes, Padua, Paris, Prague, Plzen, Silesian University of Technology, Warsaw, …[5]

ISSUE 4

Are there technical limitations to substitute fossil fuels with renewable energy, including biomass, or other alternative energy sources in heating and cooling in industry? Are there environmental and economic limitations?

There is no technical constraint to substitute fossil-fuel with electrothermal technologies (with the exception of those technologies where the fossil fuel is needed for a chemical reaction). From an environmental perspective, such substitution would be highly beneficial[6]. The **main barrier is economic**. Even though it could produce many productivity benefits, a price factor of four between the industrial prices for gas and electricity currently limits the use of electrothermal processes to about 10% of process heating applications.

With lower price factors – which could become reality at moments of abundant renewable generation – the penetration of electrothermal technologies could be much higher. A progressive switch to these technologies could very well be promoted in the context of increasing penetration of renewable energies in the electricity generation mix. Suitable market design is needed for the adoption of the full potential of electrothermal applications to provide flexibility services to the electricity system.

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[5] See membership list of www.uie.org

[6] Provided that the electricity system continues to decarbonize.

Issue Paper IV - Linking heating and cooling with electricity

Issue 1

"What steps to take to link heating and cooling and electricity systems?"

The inherent efficiency of electricity at final use, combined with the ongoing decarbonisation of the electricity system provides a powerful combination to contribute to an efficient and environmentally beneficial heating and cooling sector. The Commission's paper makes a number of valid observations and suggestions about how electricity, especially renewable electricity, could be usefully linked with the heating and cooling sectors. In particular, it notes that

"Individual heating and cooling systems of residential, tertiary and industrial buildings can also play balancing and storage functions when linked to smart electric grids. Smart electric pumps, for example, can be programmed already today to switch on when electricity is cheap. Thermal storage in the form of hot water tanks exists in many households. … However, for electricity, some encouraging progress has been recently made in the US[7]. Heat storage (e.g. in water) is a mature technology, commercially available since many years in the form of domestic and industrial hot water and ice storage systems. Under the EU FP7 and Horizon 2020 research programmes, several projects are under development to provide advanced compact storage systems that would increase the performance of the current water based equipment by a factor of above 6-7[8]. The development of such new technologies targets very low energy buildings"

Building Energy Management (BEMS) and Home Energy Management (HEMS) systems are a key technology which will need to be integrated into these developments to both facilitate the integration of the thermal and electrical energy markets and also deliver a very large part of the savings potential in their own right. In particular, they will need the development of Building Automation Technology (BAT) to deliver this potential. Zoning of heating systems and individual sensing and control of spaces and of heating or cooling elements provide huge saving potentials. BAT can also facilitate the intelligent management of thermal storage. As BAT is already proven, offers substantial savings and is already highly cost effective, it can be deployed on its own merits without a need for financial incentives. However, it needs a coherent set of public policies to promote their savings and to ensure its compatibility with the integration of energy markets.

Creating flexibility in heating and cooling systems (as will be needed for smartening the grids - an important idea in Issue IV) should go by:

1. Increasing demand response and demand management functionality (which in their turn require a proper application of automation and control)
2. Integrating storage facilities

A sectoral approach could be adopted.

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[7] Tesla http://www.teslamotors.com/powerwall.

[8] FP7 projects "COMTES", MERITS", "Sotherco", H2020 projects "CREATE", "TESSe2b".

Residential sector

First it should be determined whether collective solutions make sense (based on the population density and type of building).

In the case of collective solutions, large heat pumps can be considered as the main heating, cooling and sanitary hot water generator. These heat pumps could be backed by biomass or gas devices (condensing boilers, cogeneration units or gas heat pumps, depending on the expected use). A collective energy management system (EMS) could help to link the control of these collective systems with a set of individual home energy management systems (HEMS) coupled with appropriate BAT[9]. The HEMS would optimise the performance of the individual heating/cooling devices and of each building system as a whole by, among other means, optimising demand as a function of instantaneous electricity prices, ambient temperature fluctuations, thermal mass and occupancy. The collective EMS would receive the ensemble of these inputs and optimise the production and delivery of heat and cold to match the demand profile. Over longer time horizons the gas back-up would be replaced by thermal energy storage systems. The use of networked EMS/HEMS would facilitate network operators to activate thermal storage mode when surplus renewable electricity is available.

In the case of individual solutions, a range of possibilities is available:

Sanitary hot water (SHW) is easy and cheap to store efficiently. SHW could be generated by electricity (ideally a heat pump, as many models are already available in the market). Increasing the size of the hot water storage vessel enables the use of abundant renewables at times of low energy demand, while avoid demands on the electricity system in the reverse situation.

For space heating, proper application of control systems and automation technologies could be the first step to consider, in order to reduce the heating and cooling demand (improved control avoids waste and optimizes system performance) and to create demand response and demand management[10]. In the transition towards full electric heating systems with integrated energy storage, hybrid appliances (heat pump + gas boiler) can offer a good compromise. As in the case of collective heating, a simple algorithm could decide at each moment which energy is to be preferred (depending principally on the instantaneous electricity price and outside temperature). Over longer time horizons the gas back-up would be replaced by thermal energy storage systems.

Proper application of cost-efficient building automated controls and technology alone could save ~1 357 Mtoe from 2015 to 2035 in Europe's homes, reaching annual savings of 98 Mtoe in 2035[11]. The average cost of these

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[9] Typically, programmable thermostats and actuators on each heat/cold emitter, weather compensators and optimisers.

[10] Offermann, M. (2014). Role of Building Automation related to Renewable Energy in nZEBs. Retrieved from: http://www.leonardo-energy.org/white-paper/role-building-automation-related-renewable-energy-nzeb%E2%80%99s

[11] See *Building Automation: the scope for energy and CO2 savings in the EU*

http://www.leonardo-energy.org/white-paper/building-automation-scope-energy-and-co2-savings-eu saving is projected to be almost six times less than the cost of the energy saved and thus provides a highly attractive investment over the technology life cycle.

Tertiary sector

Similar to the residential sector, the first question is whether collective or individual solutions are to be preferred. A fully functional building energy management systems (BEMS) linked to appropriate building automation technology (BAT) could not only manage the thermal energy needs of the building, but also optimise the management of the other electrical loads (lighting, ICT, etc.). Optimal application of BAT in tertiary buildings has been estimated to offer a cost-effective cumulative energy savings potential of ~740 Mtoe to 2035 in Europe's tertiary sector buildings, reaching annual savings of 50 Mtoe in 2035 and to offer a benefit cost ratio of over eighteen to one. As is the case in the residential sector, electro-thermal storage facilitation and deployment in tertiary buildings could be facilitated through a set of coherent polices to promote BEMS/BAT with thermal storage control and management functionality integrated within them. The promotion of one could thereby seamlessly enable the other at little extra cost and within a highly favourable cost-benefit profile.

Industry sector

As noted before, with the exception of those processes where the fossil fuel is needed for a specific chemical reaction, there is no technical constraint to substitute fossil fuel with renewables-based electrothermal technologies.

This route provides a highly relevant opportunity to link heating & cooling in the industrial sector with the electricity sector. A massive switch to electrothermal technologies represents a challenge and an opportunity for the electricity system. The challenge is to accommodate a significant amount of additional electricity demand. The opportunity is that most industrial processes have inherent flexibilities (particularly those involving thermal flows) that could provide flexibility services to the electricity system and represent a cost-effective option for the integration of high shares of renewables.

Demand side management (DSM) in industry remains largely untapped[12] and conditioned by the old paradigm of the traditional electricity system: mostly devoted to limit peak demand in a few critical hours / days in the year (interruptibility contracts). However, for the future electricity system, a much richer scenario appears for the valorization of industrial flexibility. Together with peak shaving options (which become of higher value as they can avoid costly peak generation units with decreasing hours of operation), industrial facilities can now take advantage of the increasing hours of high availability of renewable generation that drive electricity prices down (which represents an opportunity to "accelerate" the production at low cost during these periods, storing a product surplus).

This new paradigm requires the development of innovative business models and regulatory upgrades to position industry as an electricity market participant on an equal footing to any other generation technology[13].

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[12] https://ec.europa.eu/energy/sites/ener/files/documents/201406_report_renewables_integration_europe.pdf

[13] Such analysis is being carried out in the context of the H2020 project IndustRE (www.industre.eu) 2015-2017. Intermediate results available from mid 2016.

A first category of business models is based on the reduction of electricity payments following consumption shifting to time-periods where the electricity costs are lower. Assuming that the low costs are reflecting real needs in a properly functioning market, industrial DSM also brings indirect benefits to renewable energy plant operators, who would face lower curtailments levels. The following models fall into this category:

- Industry reacts to price signals provided by the energy supplier. Such an energy supplier could potentially be a renewable energy plant operator, in which case the industry helps balancing its generation portfolio. For the specific case of industries with on-site renewable generation facilities, a non-discriminatory regulation is needed to allow industry to fully exploit its self-consumption potential.
- Industry procures electricity from the wholesale/spot market, either directly or through an aggregator. In this case there are more opportunities to benefit from fluctuating prices, especially in the case of on-site renewable generation facilities, as industry could sell the excess generated electricity and use its flexibility to maximise the related revenue.
- Industry reduces its peak demand, which results in lower requirements from the grid and lower access fees (the fixed term of the electricity bill). The application of this option might be restricted by the production capacity of the industry and its production requirements, unless there is on-site renewable generation, or other generation capacity that could allow peak demand to be reduced while maintaining full operation close to the peak production capacity, when necessary. This model indirectly contributes to balancing and lowering the pressure for future increases in generation capacity at system level.

A second category of models is related with offering services to the power system, which contributes to lowering the costs of maintaining the required power quality and helps to defer investments in the transmission and distribution networks.

- Industry offers, either directly, through a party responsible for balancing, or through an aggregator, its modulation capacity to the transmission system operator for primary, secondary and/or tertiary regulation. The details on how this could work in practice vary between countries, with respect to minimum thresholds, time periods, rewards, requirements for automatic activation, etc.
- Industry offers other kinds of services to the system (up to now, very few markets in which consumers participate have been established in the EU). These services include long-term generation investment deferral (e.g. capacity markets); network congestion management; reactive power control, distribution system services including peak demand shaving, active and reactive power control, voltage support and contribution to distribution network security.

At the moment the feasibility of these business models remains limited and strongly dependent on country specific circumstances. Clearing the way to enable these business models to thrive extensively throughout Europe would allow the full DSM potential in industry to be unlocked, thereby establising a solid link between the heating & cooling and electricity sectors and supporting higher penetration rates of renewable energy in the electricity system.

Finally, a clear roadmap for a progressive migration from fossil fuel to efficient electrothermal technologies should be established, which can be incentivized either directly or indirectly.

Additionally, heat pumps can be installed to increase the temperature level of residual heat flows up to usable levels. Such pumps consume electricity and could very well be flexible in their operation according to the peripheral conditions (electricity price, residual heat availability, heat needs of the industry...). Finally, when the residual heat flow has a sufficient temperature level, electricity generation can be considered as well. These two avenues would bring additional linkages between heating & cooling and electricity.