Balancing Demand and Supply within Future Systems

PeTeR TzScHeUTScHLeR, DIeTRIcH ScHMIdT, EVGUeNIY ENTcHeV ANd SøReN ØSTeRGAARd JeNSeN

The fossil fuel dependent energy landscape is changing from demand led to cultivating renewables. As a major energy consumer, the buildings sector must adapt. And while good cross-sectoral integration can aid this transition, the boundary with the transportation sector is blurring.

Within the buildings sector in industrialised countries, there is currently a large energy demand for space heating and cooling to satisfy occupant comfort. Also, domestic hot water needs to be generated and electricity has to be supplied for lighting and an increasing variety of equipment and appliances. So, measures to reduce energy demands and related CO_2 emissions from building services and occupant activities have to be implemented to achieve the ambitious goals set by governments.

Renewable energy sources are often seen as ideal for future energy supplies, but their availability is related to unpredictable weather conditions. Therefore, system integration of resources such as wind or solar energy is challenging.

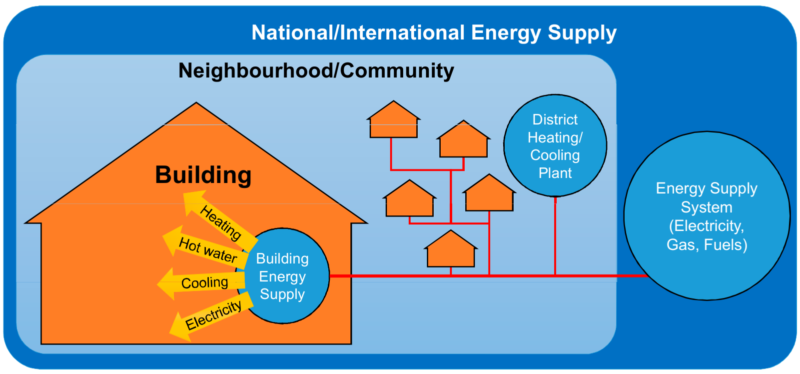
As a further trend, electric and hybrid vehicles are expected to become commonplace in the future. These will be charged from building- and community-level electrical distribution networks, contributing to increased demand in the buildings sector.

Reducing demand in buildings

For both new and existing buildings, measures to reduce energy demands and related CO_2 emissions need to be implemented by following three steps:

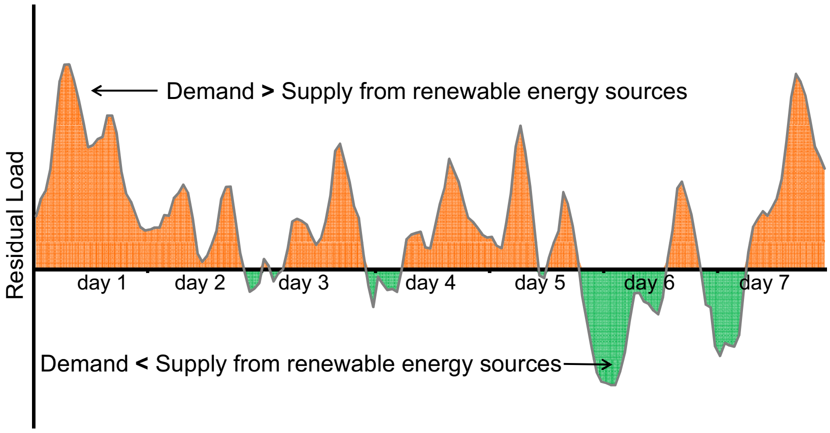
1. reduce energy demands, mainly through improvement of the building envelope (enforced by codes or regulations, for example) to achieve well insulated and airtight buildings, enabling more efficient energy use;
2. increase the overall energy efficiency using advanced technologies to reduce losses in all energy conversion and supply processes: this can be applied

Building energy supply at different scales



THe eLecTRIcITY GRId INFRASTRUcTURe ANd OpeRATION Need TO Be RedeSIGNed TO HANdLe THe New SITUATION OF UNpRedIcTABLe eNeRGY FLOwS. SIMILAR deVeLOpMeNTS cAN Be SeeN IN THe HeAT SecTOR. DISTRIcT HeATING SYSTeMS OFFeR AN OppORTUNITY AT A cOMMUNITY ScALe TO UTILISe wASTe HeAT ANd deceNTRALISed HeAT pROdUcTION FROM ReNewABLe SOURceS, FOR eXAMpLe SOLAR THeRMAL SYSTeMS. SOURce: PeTeR TzScHeUTScHLeR

Residual load of energy demand against renewable energy supply



THe ReSIdUAL LOAd RepReSeNTS cONSUMeR deMANd NOT cOVeRed BY ReNewABLe eNeRGY GeNeRATION. THe STeep GRAdIeNTS THAT RequIRe HIGHLY FLeXIBLe pOweR pLANTS ARe cLeARLY VISIBLe. ON THe OTHeR SIde, peRIOdS OF eXceSS ReNewABLe pROdUcTION Occur THAT cAN Be eXpLOITed BY eNeRGY STORAGe OR LOAd SHIFTING. SOURce: BASed ON dATA pROVIded BY FRAUNHOFeR IWeS

to single buildings, as well as at the neighbourhood and community levels by interconnecting buildings with electricity and thermal networks;

3. integrate renewable energy supplies to cover the remaining energy demand.

Demand transformation

Electricity from renewable sources will be a major component of future decarbonised energy supply systems. Indeed, changes are already underway influencing all sectors from typically demand-dependent production to supply driven markets. For buildings, this implies more common use of electricity for heating purposes may be expected, preferably employing high efficiency systems such as heat pumps. In this way, heat and electricity generation can be cross-linked. Small decentralised systems, such as photovoltaic panels or combined heat and power (CHP) units, will increasingly be used to generate electricity. Often these are building integrated, transforming the sector from energy consumers into active market participants as so-called 'prosumers' (producers who are also consumers).

Renewables brought into line

Presently in industrialised countries, energy demand for buildings has been mainly covered by using increasing amounts of fossil fuels. While these energy resources can be stored and supplied in large quantities to coincide with demand, their future availabilities and prices are uncertain.

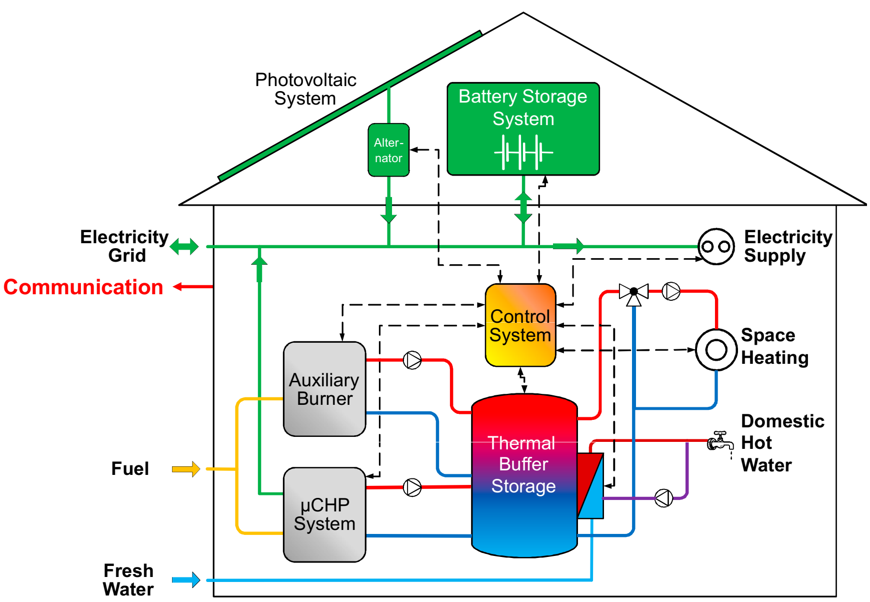
Renewable resources commonly exploited at the building or community scale are subject to weather conditions with limited short term predictability, particularly for wind or solar energy. Other renewable energy sources are generally predictable, including geothermal heat or tidal power, although these usually require large scale generation. If fluctuating renewable sources eventually dominate electricity production, other forms of production may not be able to even these out. New approaches are therefore necessary and synchronizing energy demand with supply will be essential.

The future role of buildings

The variety of practical energy supply systems for buildings has increased in recent years. Also, large scale energy supply infrastructures are undergoing significant changes to incorporate more renewable energy sources. Because of the characteristics of buildings and their significant energy demands, they will take on a primary role within future energy systems. Some aspects of this role lie in the nature of their construction, while others can be implemented in energy supply systems. Bringing together the issues of demand reduction, supply stability and integration of electric vehicle charging is a major R&D challenge for developing future systems for buildings and communities.

The existing building stock has a large thermal mass that can be activated and used as heat storage capacity for cross-sectoral load shifting. During times of excess generation from renewable energy supplies, building mass can be heated up to store energy. During short

Energy supply technologies for modern buildings



THIS SHOWS AN EXAMPLE OF AN ENERGY SUPPLY SYSTEM WITH WHICH A BUILDING COULD BE EQUIPPED. AS AN ALTERNATIVE TO A CONVENTIONAL GENERATOR, A MICRO-COGENERATION UNIT (µCHP), A SOLAR THERMAL SYSTEM, OR A HEAT PUMP COULD PROVIDE HEAT, WITH A PHOTOVOLTAIC SYSTEM GENERATING ELECTRICITY. INTEGRATED THERMAL AND ELECTRICAL STORAGE CAPACITIES EVEN OUT FLUCTUATIONS ON THE DEMAND AND SUPPLY SIDES. THE TASK OF THE CONTROL SYSTEM IS TO OPTIMIZE THE OPERATION OF THE DIFFERENT COMPONENTS WITHIN THE BUILDING, BUT ALSO IN COMBINATION WITH THE SMART GRID. FOR WARM CLIMATIC CONDITIONS, A CHILLER MAY ALSO BE ADDED TO THE SYSTEM.
SOURCE: EBC ANNEX 54

periods of power shortages, thermal inertia can reduce the required power consumption of heat pumps, for instance. However, as occupant comfort has to be maintained, advanced control systems have to be applied taking into account building thermal behaviour. Increasing the thermal storage capacity of buildings by adding additional buffer tanks for heating and DHW systems is generally straightforward.

Energy flexible buildings will be active participants in future smart grids in their role as prosumers. One already established supply technology for buildings is micro-cogeneration of heat and electrical power (µCHP). Currently, the majority of systems are based on internal combustion engines with capacities typically between 1 kW and 10 MW electrical output. Recent developments have led to the market entry of small scale Stirling and fuel cell systems with capacities of a few kilowatts. These systems are able to provide heat, cold and electricity to single buildings with high efficiencies. Many of these systems can be interconnected to form virtual power plants.

Power-to-heat technologies use electricity to provide heat at a useful temperature level. These range in complexity from simple electric resistance heaters integrated into thermal storage vessels to more advanced electric heat pumps or chillers. The reverse path from power-to-fuel, especially power-to-gas, is currently an R&D topic: Low cost electricity could be used to perform electrolysis, hydrogen production, or methanation to produce a natural gas equivalent that can be fed into the gas grid. The scale of such a plant would be in the range of several megawatts or higher.

The emergence of smart energy networks

Currently, energy is delivered as needed to buildings and community systems through separate electricity, gas and heat networks. Over time, these have been developed in centralized arrangements. They are designed to balance supply and demand in real time, with unidirectional and centrally managed energy flows. However, with the advance of distributed energy generation technologies, higher penetration of renewables and the development of information and communication technologies (ICT), the existing ageing energy distribution networks are becoming bottlenecks for achieving energy and CO_2 emissions reduction goals.

A smart energy network (SEN) is a new concept that allows integration of main energy carriers (usually electricity, gas and heat) into one network under common ICT for better management, efficient use and increased participation of distributed generation and renewables. The integration between the carriers leads to asset sharing, common intelligence and energy supply risk mitigation. SENs will be resilient, smart and interactive, exchanging energy flows and information internally and externally, providing a base for optimal energy delivery to the customer. Cross-linking technologies such as power-to-gas, power-to-heat, micro-generation, and so on, will provide interfaces between the networks for optimal energy supply.

A technology with good potential to be used in cross-linked SENs is district heating. Innovative systems, such as very low temperature heat networks with supply temperatures of under 50°C permit very efficient use of heat pumps, the integration of environmental (ground) heat or heat from solar thermal systems, and have low distribution heat losses. With this approach, waste heat can also be distributed to buildings via district heating networks. In addition, ground heat storage and water based thermal buffer tanks may be integrated. These systems are most suitable for new development projects, but the technological solutions have also the potential to be used in retrofit projects.

Research outlook

ICT will become integral to linking technologies and multiple buildings within smart energy neighbourhoods to manage network loads in real time through micro-grids, ranging in scale from individual buildings and clusters of buildings through to the community level. Micro-grids must be able to autonomously and optimally meet demand efficiently using a range of distributed energy resources. At the same time they will be able to assist other energy networks, either by accommodating the load directly or by converting the excess energy to a form acceptable by others. The initial step will introduce sensors and software information agents for informed management decisions at the network level.

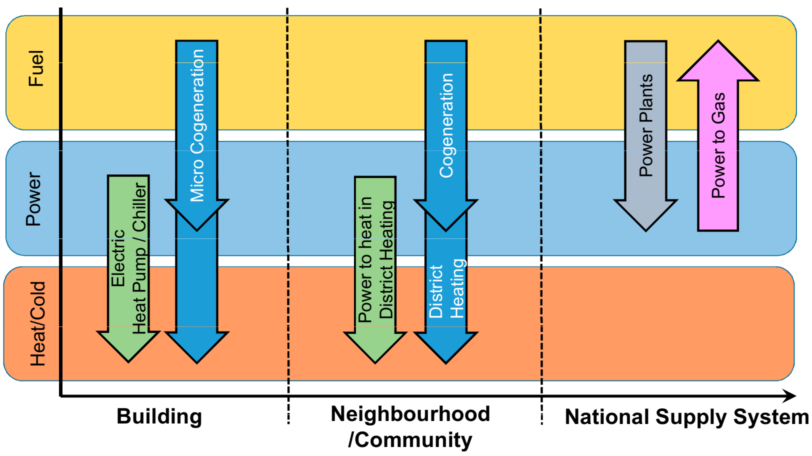
The integration of technologies for cross-linking heat and electricity networks at the building level is a current research area, due to the often unpredictable nature of the loads. System operation can be improved by implementation of energy storage systems and cross-linking of buildings. The focus is presently on larger systems for neighbourhood or community scales. Further work in this field is needed to understand how to operate these new dynamic energy systems and on how best to integrate the various components within the overall system. The integration of the transportation sector is a further aspect that needs to be addressed. The latest outcomes from EBC R&D projects have started to resolve these issues, including those from:

- 'Annex 54: Integration of Micro-generation and Related Energy Technologies in Buildings',
- 'Annex 64: LowEx Communities - Optimised Performance of Energy Supply Systems with Exergy Principles', and
- 'Annex 67: Energy Flexible Buildings'.

More information

www.iea-ebc.org

Cross-linking of fuel, heat and power at different levels



IN FUTURe, THeRe wILL Need TO Be cLOSeR LINkAGeS BeTweeN FUeL, HeAT ANd pOweR. BOTH MIcRO-cOGeNeRATION ANd pOweR-TO-HeAT TecHNOLOGIeS eNABLe BUILdINGS TO AcTIVeLY cONTRIBUTe TO GRId STABILITY ANd ALLOw THeM TO pARTIcIpATe IN THe SMART GRId. THIS cAN Be BY deMANd SIde MANAGeMeNT OR deMANd ReSpONSe. HIGH eLecTRIcITY USING BUILdINGS ARe ALReAdY AGGReGATed BY SeRVIce pROVIdeRS, FOR eXAMpLe cOLd wAReHOUSeS, ANd THeIR eNeRGY FLeXIBILITY IS AVAILABLe TO THe MARkeT. SOURce: THe AUTHORS