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## Abstract

Buildings are an essential part of the wider energy system. A significant share of electricity consumption occurs in buildings. Traditionally buildings have been places where electricity is consumed. Now they have a growing role also as a location where renewable energy production, such as solar power, occurs.

Demand response means the voluntary actions that are taken on the customer side as a response to something on the demand side. In practice, demand response can involve, for example, reducing the energy consumption during the peak times of the larger energy system or shifting the timing of the building's energy consumption by synchronizing it with local renewable energy production's profile inside the building. The building codes of Finland direct the designers' energy-related solutions both in new construction and licenced renovations.

In this conceptual paper the literature related to demand response and regulation is reviewed, and it is discussed what kind of a role the building codes could have in advancing the buildings' preconditions for demand response. Demand response is currently brought out in EU directives in the regulation with relation to network operators. However, preparedness for demand response could also be advanced by giving more attention to the timing of power use in the building codes.

**Keywords:** Building Codes, Demand Response, Energy Law, Energy Use, Power

# 1. Introduction

The balance between supply and demand in electricity networks has traditionally been achieved mainly by controlling the output power of generators. However, the role of the demand side may be growing. According to the newer paradigm, the system can be more efficient and environmentally friendly if also the fluctuations of demands are controlled (Albadi and El-Saadany, 2008).

Historically, night-rate electricity (and seasonal time of use) tariffs have been time-based incentives that encourage the timing of electricity consumption to those periods of the day or year when consumption without such pricing incentives would be lower. Hot water dispensers and both fully and partially storage heating systems in buildings have been tuned to work at night especially in many of the buildings built in Finland after the 1970s. A more recent step is electricity exchange (Nord Pool)-based consumer energy pricing, which has become increasingly popular. Electricity prices vary seasonally, daily, and hourly in the electricity markets; this variation is based on many factors, including the estimated balance situation (demand and supply). Building's energy consumption varies during different hours (Dirks et al., 2015; Vihola et al., 2015). Market price signal-based demand response can aid in the balance between supply and demand on the wider energy system.

In the future, a growing share of the electricity production will be based on intermittent generation with variable power output (Brouwer et al., 2014). The possibilities of managing the energy system by controlling the production side of electricity are more limited when the share of weather-dependent renewable energy resources (i.e., wind and solar) increases in the energy system. This is especially the case when the power is expected to be flexible upwards. Thus, there is a growing need for managing the demand-side resources of the built environment, including controllable loads, energy storages, and small-scale power generation. As a result, buildings that have been passive consumers in the energy system are expected to be more active and flexible parts of future smart energy systems (Bulut et al., 2015). At the same time, it is possible that profile of peak electricity demands in the building stock will change in the future (Dirks et al., 2015).

It is estimated that buildings account for approximately 20-40 % of energy consumption in different countries (Pérez-Lombard et al., 2008;), representing approximately 32 % of the worldwide energy demand and approximately 39 % of the total energy consumption in Europe (Allouhi et al., 2015). The need to increase the energy efficiency of buildings is nowadays recognized, and presently, energy regulations of buildings are under change. New houses should be "near zero energy buildings" (nZEB) in the European Union (EU) countries in the near future, following directive 2010/31/EU. Exceptions of this requirement include the smallest buildings and buildings that are intended to be used annually for a limited time; otherwise, most of the heated new buildings will be at least nZEB level in the future. "Near zero energy" regulations are a step towards meeting more energy-efficient requirements. The aim of the nZEB level building codes is to increase the energy efficiency of buildings and the share of energy that is produced from renewable sources. In practice, those requirements will likely increase the share of weather-dependent and small-scale energy production, e.g. solar energy and heating pumps and, in the built environment, which can influence the entire energy system.

# 2. Basics, advantages and problems of demand response

According to Darby et al. (2013), there are three approaches by which smart grids can reduce greenhouse emissions: (1) reduction of demand alias energy efficiency, (2) reduction of demand at peak times, and (3) increased penetration of renewable energy generation. In smart grids, it is possible to manage and reduce the demand peaks by changing the demand loads in such situations that previously were and currently are handled with energy generation from fossil energy sources. After the Paris Agreement in 2015 regarding global average temperature development, there will probably be growing pressure to develop energy systems towards such solutions that reduce greenhouse gas emissions.

Demand response (DR) denotes several types of voluntary actions that are taken on the customer side as a response to something in the energy system (Torriti et al., 2010). In practice, demand response can mean, for example, shifting energy consumption to a different time or reducing the energy consumption during the peak times in the larger energy system. The execution of demand response can be based on the energy price signal or, for example, on reliability (i.e., system security, capacity, or power balance based needs)-based actions (Aghaei and Alizadeh, 2013). Humans can have either an active role in controlling the loads in demand response or more passive roles, if DR is based, for example, on automated load shifting (Torriti, 2014). End users can have an active role, if households are, for example, scheduling their cooking times based on energy prices. Possible loads for automated load shifting, i.e., shifting that the end user does not necessarily even notice, when DR occurs can include the heating loads of buildings or boilers.

There are several papers on demand response from the perspectives of electricity retailers, distributors, producers, users, and DR technology (Kim and Shcherbakova 2011; Ruester et al., 2015; Shariatzadeh et al., 2015); however, the role of building codes has thus far nearly always been missing from studies related to DR and its opportunity to become more popular. In this paper, we consider how the demand response might be advanced by building codes and the instructions related to them. The regulation examples are written especially from the Finnish perspective, but many of them are also applicable in many other countries. The focus in this paper is on the forms of demand response actions where the end user can have a rather passive role: in this case, the holder of a building’s electrical interface might need to commit to take DR in use but not personally or actively follow the demand situation.

By DR it is possible to affect environmental impacts of energy production. DR can aid in reducing $CO_2$ and other emissions if it is utilized to change the timing of energy use from the peaks, when fossil energy is utilized more frequently in the energy system, to those times when fossil energy sources are not needed as much (Cardell and Anderson, 2015; Gilbraith and Powers, 2013).

Smarter demand response actions were previously possible for only large energy users, e.g., industrial actors; however, with technological development, the situation may be changing (Ruester et al., 2014). One development is that there are currently some technological preconditions in the buildings, such as smart meters and other solutions, that can enable the use of real-time price information concerning individual consumers' consumption; the lack of such preconditions was earlier seen as a potential barrier to the realization of DR (Torriti et al., 2010). In addition, the amount and role of distributed energy generation is growing (Ruester et al., 2014), which can increase the need for DR. It can be most profitable for the building's owner if, for example, the solar energy produced in a nearby building is at least for the most part also used in that building. Such a situation requires synchronizing at least part of building's energy consumption with the local fluctuating energy production.

There are several technological possibilities for implementing load control in practice. In addition to smart meters, larger buildings normally have some type of building automation system. Technically, DR can be carried out by smart meters or separate appliances, e.g., a home energy management system (HEMS). Also for example electric alternations can be utilized in managing or controlling demand need variations inside the building.

DR can provide different advantages for different market players in the energy system. These advantages include system level power balance and frequency control for the transmission system operator; portfolio optimization and novel pricing structures for the electricity retailer; peak cutting for the distribution system operator; and new possibilities for minimizing the purchase costs of electricity for the end user (Aghaei and Alizadeh, 2013; Shariatzadeh et al., 2015). If DR cuts the peak demands and improves the reliability of the energy system, then it can also reduce the need for additional power plants and committing capital costs to those investments (Siano, 2014). Feuerriegel and Neuman (Feuerriegel and Neumann, 2014) argue that the financial benefit of DR could increase in the future due to rising energy prices, increasing price volatility at different times, and regulatory reasons (Feuerriegel and Neumann, 2014). The possible advantages of DR include the following:

- **End user:** Decreasing electricity purchase costs, optimizing the utilization of energy produced in users' local power plants, and optimizing the size of the main fuse.
- **Retailer:** Optimization of the procurement of the electricity (portfolio optimisation), management of the balance between procurement and sales, novel products and pricing structures, and new business opportunities (e.g., operating as aggregator).
- **Distribution System Operator (DSO):** Peak cutting in normal and disturbance situations, using demand response as a substitute for back-up lines, and optimizing the dimensioning of the network.
- **Transmission System Operator (TSO)**: System-level power balance and frequency control (balancing and reserve power) in normal and disturbance situations.

Both the amount and the reaction time of demand-side resources are important from the perspective of energy system management. The speed at which the load can be changed based on demand affects that capacity's market value (Valtonen, 2015). In addition, the length of the possible elasticity is meaningful for its value.

Significant potential DR resources in Finnish buildings include the electric heating loads of detached houses and ventilation, cooling, and lighting in larger buildings. When utilizing demand response, several types of restrictions must be considered, e.g., indoor air quality (Alimohammadisagvand et al., Forthcoming). In addition, pre-heating of cars, supplementary electric heaters, greenhouses, and freezing plants provide load control resources.

Currently, in Finland, almost every electric customer has a smart meter (~97%), which is remotely readable, registers hourly consumption, and has some load control enabling functionalities. Furthermore, the balance settlement is based on the measured hourly energy consumption of the end-users. It is estimated that Finland could currently have approximately 1800 MW of such controllable loads via smart meters, which are, in principle, technically ready for the utilization of DR, but in practice, there are obstacles for utilizing it (Honkapuro et al., 2015).

Several market places for DR and other flexible resources already exist in Finland. There are the day-ahead (Elspot) and intra-day (Elbas) energy markets offered by electricity exchange (Nord Pool) and the balancing and frequency-controlled reserve power markets offered by TSO (Fingrid Oyj). However, the holders of buildings or apartments are normally not wholesale electricity market parties. Thus, they cannot sell their own loads directly to these electricity markets; instead, they require a third party to join that market and connecting potential loads together. The business ecosystem for DR should be further developed, though some possibilities for smaller electricity users to participate in DR have recently emerged.

Though time-based pricing (night-rate tariff) was popular even before the electricity markets opened and although DR has been part of industrial and academic discussion for some time, a more developed, energy-market-based DR has not been rapidly adopted. Electricity market parties do not appear to have high incentive for developing DR markets. According to Kim and Shcherbakova, the main challenges that DR programs have met can be classified as consumer, producer, and structural barriers. Consumer barriers include the consumer's knowledge, the availability of required technology, fatigue related to continuously responding, technological costs, and the low level of real savings, whereas structural barriers include rate structures, technology, regulatory process, and policy support (Kim and Shcherbakova, 2011).

Greening argued that the reason for slow popularization of DR is not technical by nature and recommended that state regulators regulate DR by developing incentive mechanisms to promote the utilization rate of DR (Greening, 2010). Van Dievel et al. (2014) noted that the consumer privacy issue can also be one potential barrier to the use of demand response for both investors and consumers. The execution of demand response goes hand in hand with accurate consumption data, and these data can include private information. Further, the potential rebound effects after demand reductions must be managed (Fuller et al., 2011)

There can also be conflicting interests between the retailer and DSO that can make the realization of DR more difficult. These conflicting interests have been analysed, for example, in network simulations (Rautiainen, 2015) that examined how peak loads in real-life network would change if the electric heating of the households were controlled according to the market prices of different market places. According to the results, the peak loads of the distribution network would increase if the loads were controlled based only on the market prices.

Cottwald et al. ( 2011) reported that DR also has potential for producing new challenges, e.g., new types of peaks in energy system. Energy-price-based demand response can change both the load profile in the distribution network and the conflict of interest situations between stakeholders. If a distribution tariff is structured based on the power maximums instead of energy use, then customers are also provided incentives to decrease their peak powers (Rautiainen, 2015). Hence, this kind of tariff would prevent the market-based load control from negatively impacting the peak power of the network. If customers are incentivized to optimize their loads according to both the system price and the distribution network load in such a way that tariffs support the total energy efficiency of an energy system, then more environmentally positive outcomes can result.

# 3. Demand Response and EU Directives

Demand response is a new approach from the perspective of legal regulation. Present market rules for flexibility in the electricity markets were created in a context when demand response was not real alternative for generation-side resources (Koliou et al., 2014).

In the EU's most recent energy efficiency directives, some changes seems to be occurring compared to earlier energy policy. According to Butenko and Sceres, there is currently "*significant discrepancy between the dominant concept of the consumer as adopted in the hard and in the soft EU energy law*" (Butenko and Cseres, 2015). In particular, in some of the soft-law-type documents produced in the EU, the position of consumers appears to be more active than before: there, consumers are described as active providers of demand response services to the markers. In addition, in the Energy Efficiency Directive (2012), the consumer's role is presented as somehow active providers, whereas in many other directives, consumers are seen as more passive (Butenko and Cseres, 2015). In directive 2012/27/EU, the significance of demand response in developing energy efficiency is explained as follows:

> *"Demand response is an important instrument for improving energy efficiency, since it significantly increases the* ***opportunities for consumers or third parties nominated by them to take action on consumption and billing information*** *and thus provides a mechanism to reduce or shift consumption, resulting in energy savings in both final consumption and, through the more optimal use of networks and generation assets, in energy generation, transmission and distribution."*

In the same directive (2012/27/EU), in article 15, it is required that European Union's member states should ensure "*the removal those incentives in transmission and distribution tariffs… that might hamper participation of demand response, in balancing markets and ancillary services procurement*", "*that network operators are incentivised to improve efficiency in infrastructure design and operation, and, within the framework of Directive 2009/72/EC, that tariffs allow suppliers to improve consumer participation in system efficiency, including demand response, depending on national circumstances*", "*national energy regulatory authorities encourage demand side resources, such as demand response, to participate alongside supply in wholesale and retail markets*" and "*promote access to and participation of demand response in balancing, reserve and other system services markets, inter alia by requiring national energy regulatory authorities or, where their national regulatory systems so require, transmission system operators and distribution system operators in close cooperation with demand service providers and consumers, to define technical modalities for participation in these markets on the basis of the technical requirements of these markets and the capabilities of demand response*".

Thus, the Energy Efficiency directive sets requirements for network and retail operators to promote demand response by their pricing tariffs. In annex XI of the same directive, time-of-use tariffs, critical peak pricing, real time pricing, and peak time rebates are mentioned as examples of network or retail tariffs that could support dynamic pricing for demand response measures. However, this directive does not set requirements for building designers or for the consumer side related to demand response.

Network regulation (Agrell et al., 2013) and energy market regulation solutions are important tools when promoting demand response. However, in the literature, little attention has been paid to how demand response could be promoted in buildings by building codes and by buildings' original designers. In this paper, it is argued that preconditions of demand response could be promoted by building codes among other regulation instruments. Next, we examine this subject using Finland's building codes as a case example.

# 4. Building Codes and Energy Efficiency

Lee & Yik classified instruments encouraging energy efficiency in buildings into three categories: (1) building energy codes, (2) incentive-based schemes, and (3) eco-labelling schemes (Lee and Yik, 2004). Building codes affect buildings' design and construction processes and, thus, its features aside from land use planning regulations. Incentives include energy taxation and energy renovation aids; in addition, energy certificates can be seen as examples of eco-labelling.

Buildings codes have a meaningful role in reducing the energy consumption of buildings (Scott et al., 2015). The use of mandatory building codes in encouraging energy savings in the buildings became widespread in the 1970s after the energy crisis. (Allouhi et al., 2015; Lee and Yik, 2004). These building codes are currently widely used instruments, especially in many developed countries, and are used among other things to control the energy consumption levels of new or renovated buildings (Iwaro and Mwasha, 2010; Salvalai et al., 2015). The content of building codes varies in different countries and areas, where climate conditions and local needs can differ. Building codes are applied in the design and construction phases of new and renovated buildings; however, such codes are not necessarily able to give orders regarding the use of the buildings or buildings products, for which different legal instruments should be used. The legal status of building codes also varies in different places: their status is mandatory in some countries or areas, voluntary in others, and mixed in still others (Iwaro and Mwasha, 2010).

In Finland, building codes (see Building Codes of Finland) have traditionally included both mandatory rules and voluntary instructions in the same documents; however, the situation is changing, and there is ongoing a process for separating mandatory parts from instruction parts by 2017. All mandatory parts of the building codes will be in the future given by decrees of the Ministry of the Environment in Finland. In this paper, both the mandatory and instruction parts given by the responsible ministry or government are called building codes.

Finland's valid Land use and construction act (117 g §) mandates the Ministry of the Environment giving building decrees about the minimum requirements for energy efficiency in buildings; building products and technical systems and their calculation methods; heating systems in buildings; improving energy efficiency; measuring energy consumption; and the minimum energy efficiency requirements based on a building's intended utilization. Mandatory regulation regarding the electricity use of buildings is focused on safety issues and is given in documents that are not classified as building codes. HPAC issues are addressed in the building codes.

Building codes of Finland are applied when building licence is sought. Building codes guide the designers' solutions, and consequently the features of the buildings. When it comes to the many details of the energy systems, building professionals make several decisions for the end users. related to the details of buildings' energy systems. Thus the designers and electricians may play a key role in how DR-ready the new or renovated buildings will be or whether DR features are utilized. However, the building codes and the design solutions can impact the user behaviour only partly and indirectly in the utilization phase.

Even though building codes are currently instruments that can be used also in encouraging towards energy efficiency, their role in predefining the probable load profile of buildings' energy use has not often been dealt with. Plans of new buildings have to be in accordance with regulations. Current building codes in Finland set limits for computational annual energy use in new buildings, which is calculated based on plan documents. However, timing profile of energy use inside the year or energy load profile of building has no weight in current regulations.

# 5. Discussion

Through building codes it is possible to set requirements for technical solutions or technical readiness issues in buildings, to guide the selection of building products utilized in buildings, and also for example determine the targets, objects and methods of energy calculations. Table 1 provides some examples how demand response capabilities in new or renovated buildings could possibly be advanced by building codes. The cost efficiency and effectiveness of the means presented in the table are not analysed in this paper. It could be a theme for further research.

The ways how demand response capabilities in the buildings could possibly be advanced by building codes could include for example changes in minimal technical requirements; changes in the other details of energy efficiency incentives; and changes in things that influence designers', buyers' and public officers' awareness of the power behaviour of buildings and how it can be affected by design solutions. In principle, it is possible to respond by demand on many levels, including the energy market level, the distribution network, and the building's own electric network. Also the regulating means listed in Table 1 can have targets on different levels.

*Table 1: Examples of how readiness for demand response could possibly be advanced by building codes (or voluntary actions related to them)*

| **Means of regulation** | **Object of impact** | **Example** |
|---|---|---|
| Defining the technical requirements so that readiness for DR grows in the buildings | Technical solutions and possibilities to exploit DR | Massive structures and boilers are often able to store heat energy in building, which can be utilized in DR. However, if HVAC systems are not easily ready for DR, those capacities are not so likely utilized. |
| Requiring that power use efficiency is noted when performing the energy calculations required for building licence | Power use behaviour of buildings | Target values for the electric power use could be set both for peak and empty use times of buildings for daily hours and different seasons. Those values could be calculated when the energy calculations of buildings are performed anyway. |
| Taking into account DR when determining the primary energy factors per energy carrier | Energy certification class & profitability of DR investments | Lower primary energy factors per energy carrier could be utilized for electricity in the primary energy calculations if DR are considered in the design |
| Instructions for synchronizing distributed local renewable energy production and energy use inside the building | Timing of energy use in comparison to timing of local energy production | The DR features of appliances could be encouraged to put into operation, when they have such |
| Instructions or recommendations for power management inside buildings | Power fluctuation management inside the building | It could be encouraged that especially larger loads, e.g., sauna stoves and heating pumps, are alternated to limit the probabilities of sharp power peaks in the energy demand of the building |

Currently, the building codes of Finland concentrate on annual energy consumption, and the timing of the consumption or the power peaks do not play a significant role. However, as noted in the literature review, the timing of consumption can be an environmentally significant issue, and influence, for example, the greenhouse gas emissions of energy production and wider energy systems. Technical solutions affect some DR capabilities. For example thermally massive structures can slow temperature changes in a building and add the possibility of changing the timing of heating. To guide the designers' and building owners' attention towards the power use instead of annual energy use alone, some target power values could be set and calculated for both peak and empty use times that could be taken into account in the design phase.

One idea that we have proposed as an incentive for DR is that lower primary energy factors per energy carrier (see 2010/31/EU, Annex 1) could be utilized for electricity in the primary energy calculations if DR was utilized. The basic idea behind those primary energy factors is to encourage reduction of the total primary energy consumption and to promote the share of renewable energy sources. If DR could help to reduce the consumption of non-renewable energy sources, then this fact might be an argument for applicability of lower computational factors. The values for those factors are nationally appointed in the member states of EU. In Finland, those factors are given as a Government Decree and published also among the building codes.

The aim of the instructions for synchronizing distributed local renewable energy production and energy use inside a building is to direct the demand inside the building towards the production time and power profile of local energy production. The same technical structure for demand response system might be applicable in other levels and types of DR. In the present smart electricity meters, there are some readiness features for demand controlling that could, in principle, be utilized in some type of DR. However, those features are often not installed for use or are not utilized if they are installed.

In Finland, the electric sauna stove and heating systems of several residential houses have been alternated via the electric installations for decades without legal commands. Those alternations have reduced the power peaks inside the building and needs for larger fuse size. However, omission of such alternations has nowadays become more common in new buildings. Building codes have not traditionally regulated electric installations in Finland, but the power behaviour of buildings could be at least indirectly guided also by building codes.

When developing regulation related to DR, also the risk aspects must be considered so that the regulation wouldn't, for example, lead to such new losses that do not exceed the benefits obtained from the perspective of total energy efficiency. For example it is possible that if DR readiness is required by mandatory regulation, the features may not in all cases be utilized in practice, at least if DR features are not sufficiently economically profitable or easy enough to use. When developing regulation, also technological development and new types of future solutions for power management should be somehow taken into account. The focus in this paper has been in such types of demand management that do not require the end user to play an active in the using phase of the building's life cycle. However, the building's owner or user may need to make decisions whether the DR features are utilized in the building or not.

# 6. Conclusions

From the perspective of total energy efficiency of energy systems, it could be useful if the power aspects were considered more in the design phase of buildings in addition to annual energy use examination. Regulation by building codes is not the only possible approach for affecting preconditions of DR, but it can be one piece of the larger puzzle, which includes also for example information issues, taxation solutions, tariff structures in distribution network and energy market regulation.

Although the load profiles of different building types vary in different countries, the need for load management and demand response ability may grow worldwide as the structure of energy production is changing towards a more renewable nature. Further research is needed about the connections of DR and effectiveness of regulation in the built environment.

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