The active role of buildings in a transforming energy market

Discussion paper

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TABLE OF CONTENTS

1 INTRODUCTION

Borders do not anymore limit today's energy market: it is increasingly decentralised and no longer a collection of national systems in which large fossil-fuel-fired power plants supply passive consumers. The significant penetration of decentralised and mostly inflexible renewable-energy-generation technologies is largely challenging the demand-supply balance in the new European energy market. On top of that, the current power-load growth due to the transition to electric transport and heating systems is pushing the power-supply system even further towards its limits.

A quarter of Europe's power already comes from renewables, but this proportion may rise to 50% by 2030. Therefore the current grid-balance challenges require energy efficiency and flexible solutions, i.e. the ability to modify electricity usage by end-use customers during system imbalances or in response to market prices. This demand response (DR) is often linked to some form of energy storage (RAP, 2013).

This challenge is acknowledged by the European Commission, highlighting in its Energy Union Factsheet that a market design is required to provide storage and more flexibility in demand response, enabling consumers to better participate in markets.

Buildings are becoming active players in a transforming energy market. As the largest energy-demand-side actor, they could play a key role in tackling the energy market's challenges, but this role has not yet been explored sufficiently. In the complex energy system, energy efficiency and innovative technologies such as demand response, storage and advanced renewable installations play a crucial role in accelerating the transformation of our homes from simple energy consumers into much more active players. This role itself will become even more intriguing than the fashionable word 'prosumer' (producer plus consumer) referring to it. (Popov, 2015)

2 WHICH DILEMMAS EMERGE?

The overall power market in the EU is transforming from a centralised, national system towards an increasingly decentralised, variable architecture, where buildings are becoming active players and global enterprises, such as Google, Tesla and Apple, are entering the market, disrupting the value chain.

This transition is a breeding ground for dilemmas leading to discussion.

2.1 Energy demand ↔ Final energy

Do the energy market and society need to reduce the energy demand from buildings in the first place, or do they need technological solutions to decrease or shift final energy? Certainly, a harmonised combination of both would be the most appropriate and viable solution. However, to decide on the limit of each approach – where do we stop improving the building envelope and switch to demand-responsive technologies, and what are the no-regret options? – planning is necessary at every level. The figure below shows the relation between energy efficiency and DR approaches, and the increasing interaction with the grid.

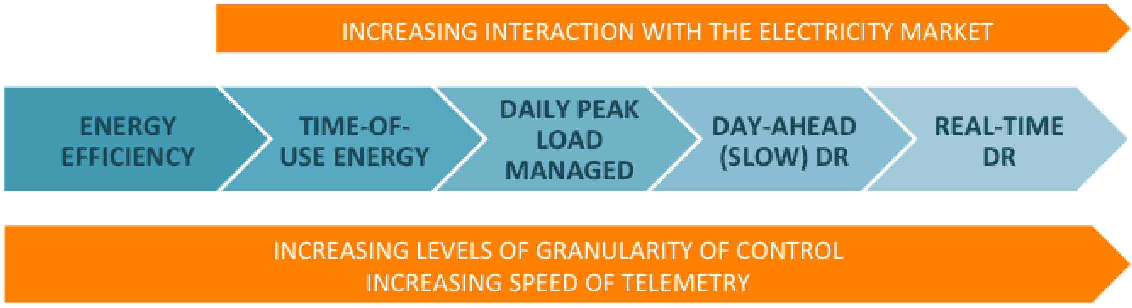

Figure 1: Relation between energy efficiency and demand response approaches related to controls and telemetry. (Based on Lawrence Berkeley National Laboratory, 2014)

2.2 Natural gas ↔ Electricity

Both natural gas and electricity demand long-term investments with consequences for future decisions. With the increasing importance of renewable electricity and its transportation between Member States, an electrification of the market seems the obvious step to take. Natural gas demand is declining in all three major sectors – power, industry, and residential – but on the other hand natural gas infrastructure could also serve for other energy carriers such as biogas and hydrogen fuel.

2.3 Renewable energy on individual building level ↔ Large-scale renewable energy

Large-scale renewable energy systems – e.g. wind farms, large PV and solar thermal surfaces, and large biomass installations – are more efficient and can easily be controlled based on energy demand and grid quality. However, small-scale building-related renewable technologies are very accessible for end-users and have an important impact on national renewable-energy targets.

2.4 Centralised storage ↔ Decentralised storage

On an individual building level, decentralised power and heat storage are feasible for shorter durations. Centralised (semi or large-scale) storage is more appropriate for longer storage durations such as seasonable storage and provides advantages for grid-related operations and economic feasibility. However, decentralised resources could provide services for longer periods of time if they are aggregated. There exists a large amount of decentralised storage already (such as hot water tanks, air conditioning, hot tubs) but it is not connected up to now. Aggregating these existing decentralised storage might be cheaper than implementing supply or grid-side centralised storage solutions.

Home-battery storage is not economical today, but through the benefits of experience and scale, the tipping point for the combination of PV systems and power storage is expected in the coming years. Plug-in electric vehicles could play an important role as decentralised power storage systems.

3 THE INTERACTION OF BUILDINGS WITH THE ENERGY MARKET

Buildings account for around 40% of the total energy consumption and 36% of the CO_2 emissions in Europe. The energy carriers or sources delivered to buildings are mainly gas, biomass, oil, heat (district heating) or electricity.

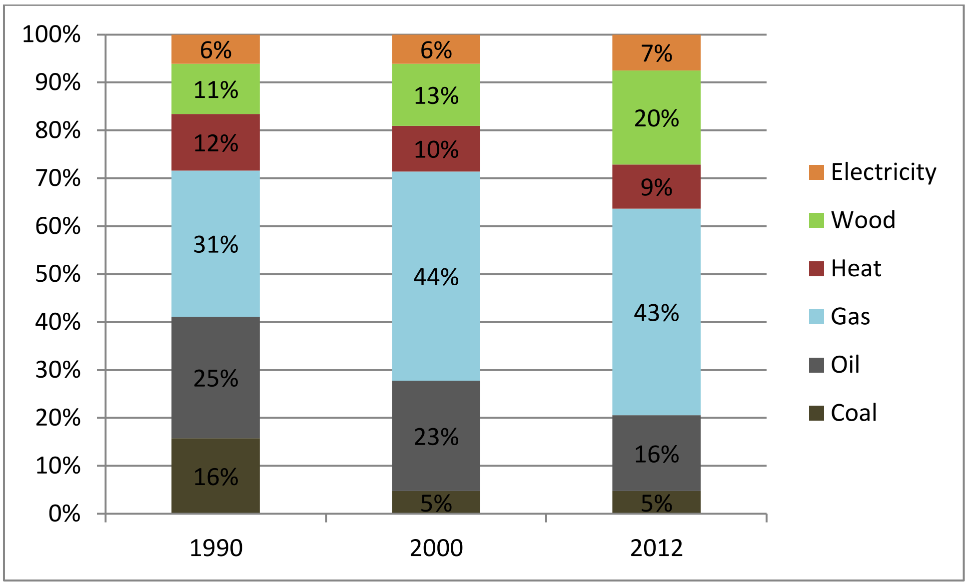

Figure 2: Household energy consumption for space heating by energy type, source: Odyssee

Although the end-use of energy depends on the building typology, the main uses are space and water heating, appliances, cooling and ventilation, lighting, and cooking.

Besides the essential demand reduction, buildings increasingly interact with the power market and could take up an important role in power-supply-system stability by providing renewable electricity production, storage and demand response. These three strategies are not only complementary, but even enforce each other.

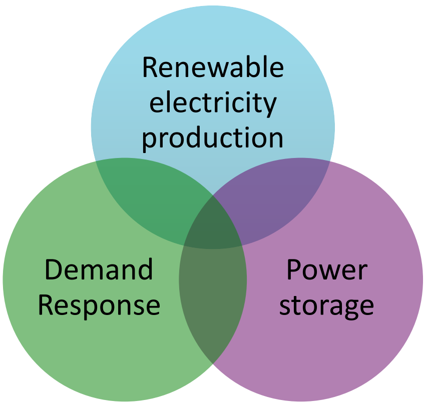

Figure 3: Strategies for buildings to interact with the power market

3.1 Demand response

Buildings are a source of flexible energy demand and storage, providing distribution and transmission system operators with the services they need to balance available supply and manage power quality at all times.

The net benefits of achieving basic market integration through implementation of the Target Model are in the region of 12.5 to 40 €bn/yr by 2030, with market reforms to enable demand response providing an additional 3 to 5 €bn/yr (Booz & Company, 2013). According to Professor Goran Strbac of the Imperial College London, flexible energy demand has an energy saving potential of 500 billion euro in Europe.

Instead of steering the supply side with power generation to balance the grid, demand response steers the power demand of energy consumers using price signals. It can be provided by all categories of consumers (industrial, commercial and residential), employing many different technologies or strategies to achieve shifts in demand (RAP, 2013). Common examples include:

- Reducing or interrupting consumption temporarily with no change in consumption in other periods.
- Shifting consumption to other time periods.
- Temporarily using on-site generation in place of energy from the grid.

In addition, DR can provide frequency regulation, load-following and other power system services. During periods of excess energy production, DR resources that have an element of storage may absorb this energy.

In buildings, DR could be enabled by new technologies such as energy management systems (EMS), smart meters, smart thermostats, lighting controls and other load-control technology with smart end-use devices.

Experience in pilot projects where time-of-use tariffs were only open to a small percentage of residential consumers demonstrate that not all consumers need to participate in a demand-response programme for it to bring important benefits. This shows that demand response can happen now, even in the absence of an optimal and complete technological roll-out and market opening. (RAP, 2013)

How DR is actually implemented in a building highly depends on the building type, present controls, and the engagement level of the building's occupants, but in general, there are three on-site approaches to implement DR in buildings (Southern California Edison, 2013).

Manual Demand Response

This approach is the most direct. Building occupants change energy-consuming behaviour and turn off or adjust energy-consuming appliances during a peak-demand event. This can be an appropriate strategy in buildings with equipment process that requires sophisticated shut-down procedures, and is the only option for buildings that do not have energy management systems (EMS) that control the building's HVAC, lighting, and/or equipment process. Manual DR is labour-intensive and prone to human error, but can nonetheless be cost-effective.

Figure 4: A manual demand-response process in a building

Semi-Automated Demand Response

Semi-Auto DR requires the use of a building EMS to carry out specific DR control sequences during a peak-demand event. This approach is less labour-intensive, but still requires human intervention.

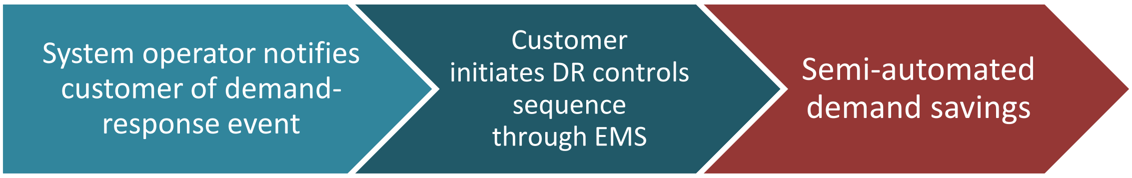

Figure 5: A semi-auto demand-response process in a building

Automated Demand Response (ADR)

An automated demand response (ADR) approach does not require intervention by the building occupant or manager because control is handed over to a third party (such as an aggregator, agent or ESCO). Auto-DR requires equipment that is capable of receiving an auto-DR signal from the demand-response automation server (DRAS), which serves as the communication link between Transmission System Operators (TSOs), Distribution System Operators (DSOs), and the customer. The building's control system must be "ADR"-compliant in order to receive the Auto-DR signal.

Figure 6: A fully automated demand-response process in a building

3.2 Renewable electricity production

The growth of renewable energy systems (RES) connected to the grid is essential to achieve a sustainable and decarbonised energy market. At the same time, variable RES put additional stress on the grid given their intermittent generation and the fact that the grid infrastructure is not ready for a large amount of decentralised production facilities.

With greater shares of variable RES, operators will need to balance net demand (i.e. energy demand minus available variable RES). Peak energy-demand hours can still be predicted but net-demand will be highly variable and only predictable close to real-time.

On-site renewable energy installations such as heat pumps, biomass boilers or solar thermal applications play an important role in improving the energy performance of a building but do not produce power and are therefore not described below. Small-scale wind, on the other hand, is less relevant.

Heat pumps (and other electrical heating systems) do matter a lot in demand-response systems because home heating is responsible for the highest use of residential energy.

3.2.1 Photovoltaic solar energy

This technology has seen a major uptake during the last years due to financing mechanisms and the approaching grid-parity. Deutsche Bank is predicting that solar systems will be at grid-parity in most of the world by the end of 2017. This is due to rising grid-based electricity prices across the world, and falling solar costs. The collapse in oil price will do little to slow down the solar juggernaut. Even if electricity prices remain stable, two thirds of the world will find solar to be cheaper than their current conventional energy supply. (RenewEconomy, 2015)

Power storage and demand response can potentially make rooftop solar more economical. These systems support building occupants to consume more PV output on-site, leading to larger cost-effective PV arrays as well as a higher customer demand met by rooftop PV rather than by utility sales. On the other hand, customers might be paid by DSOs/TSOs to supply to the grid rather than to self-consume at certain times.

3.2.2 Combined Heat and Power

Combined heat and power (CHP), also known as cogeneration, is a technology using an engine to generate electricity while simultaneously capturing ‘waste’ heat from an engine exhaust for energy recycling. CHP can operate with a biogas or biomass fuel supply, making it a renewable energy source.

Traditionally it is reserved for large industrial facilities due to their enormous need for both thermal and electric energy. However, recent technological advancements have led to higher efficiency and lower costs, making the so-called micro-CHP viable in new market sectors, such as (collective) residential dwellings, public and commercial buildings. Furthermore, it is a very convenient heat supply for district heating systems.

As part of a future decentralised energy market, micro-CHP units can be aggregated as a ‘virtual power plant’, dispatched when the intermittent renewables are not generating sufficient power. The start-up speed for micro-CHP is high, compared with much larger base-load power plants, offering additional advantages to flexibility. (Delta-EE on behalf of COGEN Europe)

Cogeneration used for building heating intrinsically matches the overall electricity demand, e.g. in colder periods, when heat pumps consume the most power, both heat and electricity from the micro-CHP are in demand.

3.3 Storage systems

In an energy environment of increased complexity, flexible technologies are highly valued. Technologies that can rapidly adapt to operating loads, absorb or release energy when needed, or convert a specific final energy into another form of energy are increasingly important in energy systems. A number of technologies offer this flexibility, including: co-generation technologies bridging electricity and thermal systems; industrial sites transferring surplus heating or cooling to local DHC networks or absorbing excess heat from the thermal grid to convert it into electricity; DHC systems absorbing power from the grid through heat pumps and storing it as heat in excess-generation periods; absorption technologies bridging heating and cooling in DHC systems, and electrical and thermal storage capacities contributing to level-peak-demand periods (see Figure 7).

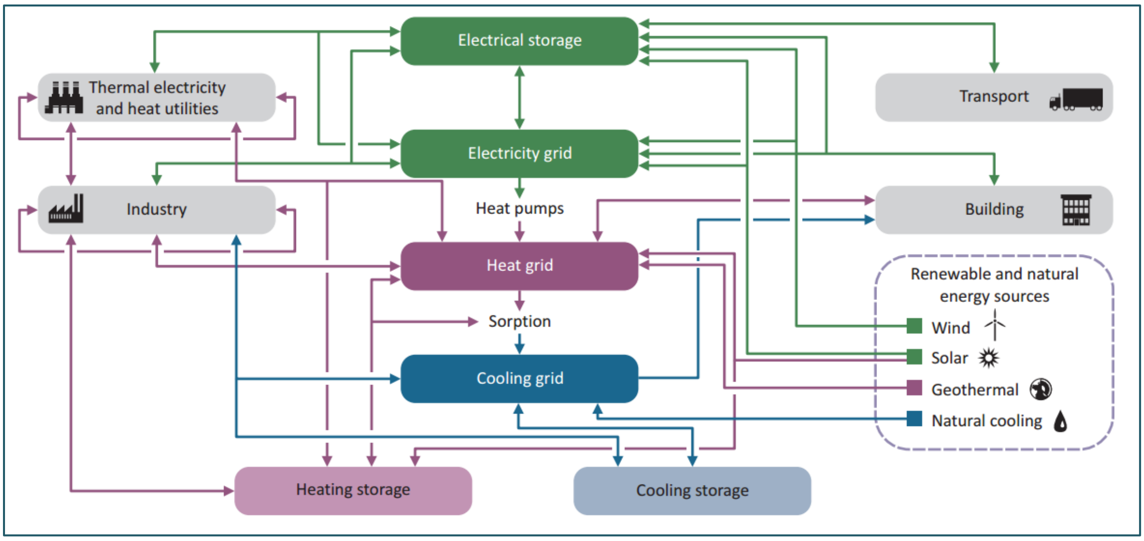

Figure 7: Interconnections of electricity and thermal energy in an integrated energy system. Electricity and thermal energy systems are complex and offer numerous opportunities for deep integration. Source: IEA (International Energy Agency, 2015)

On the level of individual buildings, power and heat storage is feasible for shorter durations. Longer storage duration, e.g. seasonable storage, has to be approached on a centralised large-scale level.

Domestic hot water storage is a well-known technology, often combined with solar thermal panels. A less common technology is the storage of heat or cold in the building mass – i.e. walls and ceilings. Phase change materials can store heat 'latently', using a process that occurs at a defined temperature level. (Mehling & Dr. Peter Schossig, 2009) By using heat storage, buildings connected to district heating can support cutting the heat-load peak, allowing the district-heating supplier to avoid running the peak-load boilers, often fuelled by conventional energy sources. (Roos, 2015)

The announcement of Tesla to enter the building market with their Powerwall made home battery-storage a 'hot topic'. It is too early to predict the concrete market consequences, but it is sure that the market is moving from innovation to a growth phase.

The battery will be handy if there are blackouts, but more important is that this type of storage enables to time-shift demand to off-peak times and reduce demand during peak periods. Flattening demand curves, especially peaks, is very advantageous for Transmission System Operators and Distribution System Operators. Therefore, the market uptake of Tesla's Powerwall might open the ground for decentralised power trading at individual building level.

Home battery-storage is not economical today, but through the benefits of experience and scale, the tipping point for the combination of PV systems and power storage is expected in the coming years. Due to the green credentials and the hype factor, it is already viable for a subset of the high-consuming market.

Plug-in electric vehicles can be controlled to recharge when wholesale electricity prices are low, to avoid times when energy resources are scarce and prices are high, and they can provide all kinds of (one-way) grid services leading to remuneration. Eventually electric vehicles might even be able to provide energy to the grid.

4 EMPOWERING BUILDING OCCUPANTS

As mentioned in the previous chapter, all categories of consumer groups (industrial, commercial and residential) can play a role in interacting with the energy market, but the differences between them have to be recognised and specific approaches need to be designed and implemented.

4.1 Industry

The EU industry is, with its sharp attention to energy costs and investments in energy management systems, the sector that has achieved most energy savings and exploitation in demand response so far, and is keen to tap the significant flexibility that remains.

Leading demand response markets demonstrate that DR uptake in industry usually precedes uptake in commercial and residential sectors.

4.2 Commercial buildings

Commercial consumers make up 30% of the total energy consumption throughout Europe. For these consumers, heating and cooling are the main sources of consumption (up to 80%), which is why commercial buildings could be seen as the immediate storage resource of Europe. These buildings can be pre-heated and pre-cooled efficiently and should be able to offer this flexibility to the market. Furthermore, demand response and energy efficiency work well together in commercial buildings. This is due to the fact that the heating and cooling controls and management systems for energy efficiency can also be used for demand response. Aggregators and Energy Service Companies (ESCOs) are increasingly exploring and using this potential. (European Commission, 2013)

4.3 Residential buildings

Home occupants have the growing ability, through the use of a variety of timers and controls, to determine precisely when during the day (or night) their home's energy hogs – like the hot water heater or the electric-car charger – draw their power.

This timing matters because it will allow home occupants to take advantage of increasingly prevalent time-varying electricity-pricing schemes, in which the power supplier charges more when energy resources are scarce and less when energy resources are plentiful and available. The Chicago-based utility ComEd, for instance, offers a program in which prices change hourly, based on supply and demand, and customers receive alerts about them.

The Rocky Mountain Institute reports that in the USA, in the residential sector alone, widespread implementation of demand response can save 10–15% of potential grid costs, and customers can cut their electricity bills by 10–40% with existing rates and technologies. Key to enabling demand response are appropriate price-signals combined with in-home 'smart devices' — notably smart thermostats and programmable timers for dryers, hot-water heaters, electric-vehicle chargers, and other large consumers of energy. Some of them already exist, like Google's Nest Thermostat for instance. (Mooney, 2015)

4.4 Challenges to empower building occupants

Given the current available systems and technologies on energy efficiency, on-site production of renewable energy, grid connection and ICT driven appliances (Internet of Things), the question should be raised whether the basic concept for a building would not change - from energy consumer through prosumer to (inter)active energy hub or micro-virtual-power plant. This change requires strategies and measures to be adapted to the building's occupants and managers needs and concerns. The challenges which the market is facing are:

- **Data security and protection**: demand response involves the processing of personal data and integration of ICT at a significant scale. Data protection, privacy and security therefor become major concerns not only for industry and investors, but also for individual consumers as data coming from frequent and remote metering and processed by smart-grid operators is classified as personal data.
- **Dynamic price signals** reflecting the real-time status of the power system, available for industrial, commercial and residential consumers: the availability of dynamic, clear and transparent energy-pricing models for consumers is key to demand response systems. Entry barriers to the wholesale electricity market are gradually being removed and dynamic pricing such as time-of-use tariffs for residential consumers are available in several Member States (e.g. UK, FR, IT, ES).
- **Individual residential loads are small.** To overcome this barrier, aggregators can collectivise these loads, an approach for white goods and an increased use of electric vehicles - with highly flexible loads - can be foreseen.
- **Smart controls and household appliances** able to temporarily modulate their energy use, without compromising their function, according to a user's stated preferences, system, load or price signals. Such signals may come directly from the energy system or through an aggregator which can also provide feedback to the consumer if and as desired.
- **Smart metering and control systems**, recording consumption during particular time intervals in power markets to enable billing, which reflects shifts of consumption to low-price periods.
- **Standards for DR signals**: a common standard for communicating to both load-control and supply-control devices will help accelerate DR implementation for utilities and device manufacturers.
- **Storage possibilities** facilitating the shift of consumption in time. These include local storage in buildings as part of their existing heat storage - a potential practically untapped at present, yet with very low costs and short returns on investment.
- The **production and use of on-site renewable energy** should be allowed and further encouraged. However, not in all Member States the instantaneous storage or use of the produced green energy is allowed or encouraged. Grid tariffs should also provide incentives, and not disincentives, to distributed generators to interact with the grid for the benefit of the system.
- **Third-party business models** (aggregators, agents or ESCOs) pulling together demand response, storage and on-site power production technologies, saving residential customers money, by control

and management services and providing technologies through a specific financing model (e.g. leasing), and optimising it for the final consumer. Mass demand response will only happen if these third parties act on behalf of consumers, but for this to happen, the business case must be viable. Aggregators have to be able to extract enough value - from a pool of resources - in order to have a business case. Therefore, the benefit for the building occupant or manager has to be sufficient to hand over control.

- **User-friendly**: many customers would only be interested in demand response and power storage if it was very practical to use, since the financial benefit at the residential level will be too limited to spend much effort in it. Value to balance the grid can be used as incentive for people to get interested in DR, but sooner or later a fatigue effect will kick in (people get bored) and therefore a reliable (semi-) automated process - whether or not controlled by an aggregator - should be put in place.

5 ISSUES TO BE ADDRESSED IN EU BUILDINGS REGULATION

Existing provisions in the EU legislation regarding demand response are foreseen in the Internal Market in Electricity Directive, the Energy Efficiency Directive, the Eco-design Directive and the Energy Labelling Directive. The current transposition of these directives is far from ideal. Without adequate national measures that enable this EU legal framework to be applied in Member States, the progress of demand response will continue to be slow. Therefore, full and effective transposition of the concerned European legislation is crucial.

The current Energy Performance of Buildings Directive (EPBD) introduced several important requirements for enhancing the energy performance of buildings in all EU Member States. However, the role of buildings in a decentralised energy market is not mentioned in it.
The European Commission launched a public consultation on the EPBD, running until 31 October 2015. This ongoing review provides a window of opportunity to address the role of buildings in the energy market.

The European Commission also launched a public consultation on a new Energy Market Design, which ran until 8 October 2015.

The active role of buildings in a transforming energy market, i.e. demand response, energy storage and on-site renewable energy production, should be encouraged more strongly by future building-related legislation and support measures. The identified issues to be addressed are the following:

- The EPBD has, to a certain extent, stimulated the deployment of on-site renewable energy technologies. However, the instantaneous storage or use of produced green energy is not allowed or encouraged in all Member States. As a result, the produced energy is injected in the public network instead of being used locally. Smarter regulatory frameworks are needed in order to maximise the share of energy being stored or used immediately and locally, especially during peak times. This is also important to clarify and limit the scope of the word ‘nearby’ renewable-energy production as it is used in the description of nearly-Zero Energy Buildings, so that behavioural measures – such as the subscription of a contract with a green-energy supplier or the financing of a local renewable-energy project – are not perceived at the same level as the installation of on-site RES systems.
- The current version of the EPBD does not stimulate energy storage or demand response measures, and does not reflect the new reality in the EU. There is an increasing share of renewable energy in the system today compared to the time the EPBD was adopted. Buildings need to be part of the solution to help the energy systems function well. The EPBD should push energy savings in (existing) buildings further, while at the same time a more flexible use of buildings is required due to the growing necessity for energy storage and on-site generation.
- The new energy market design has to lead to the availability of dynamic price signals for industrial, commercial and residential consumers, reflecting the real-time status of the power system. It should

be ensured that the true value of flexibility is exposed in the energy markets and concerned actors have full access to this value and retain it by minimising discretionary costs.

- The smart meters being installed in various European countries should be equipped with support to home networks and allow dynamic price models. End-users and other relevant actors, such as aggregators, ESCOs, installers and energy auditors, should have detailed access to data from smart meters, EPC or building automation systems. With this access, the building performance, comfort and indoor air quality can be further improved.

6 CONCLUSIONS

The overall power market in the EU is transforming from a centralised, national system towards a more decentralised, interconnected and variable architecture, where buildings could become active players in the energy system.

In a complex energy environment, a more active role of the existing and future buildings' infrastructure within the energy market is a key innovation to be unlocked, with large value to be captured. The active integration of buildings allows for fast adaptation to operating loads, increases the penetration of building-integrated PV and other renewable-energy systems, and allows balancing and decreasing the load on the grid.

The enabling measures for this transition are:

- At a political level, a comprehensive vision on the integration of demand response, renewable energy production and storage in buildings.
- An enabling regulatory framework which encourages this buildings' integration.
- The availability of dynamic price signals for industrial, commercial and residential consumers.
- Smart and user-adapted metering and control systems.
- Aggregators supporting the different consumer groups.

Energy efficiency and the interaction of buildings with the energy market are crucial for meeting future energy needs with the lowest supply and transmission capacity, and associated costs. This transformation would be beneficial to all kinds of consumers, including households facing increasing energy bills, commercial businesses and industrial players that need to compete with companies from countries with lower energy costs.
Through the benefits of experience and scale, the tipping point for the combination of renewable energy systems and power storage in buildings is expected to be reached in a few years. In addition to that, demand response applications are suitable in particular for buildings without renewable energy production, since their consumption during peak hours is mostly higher.

Demand response and buildings battery-systems can easily be integrated in existing buildings, but they are not yet at full market maturity. To be commercially competitive, these technologies require strong marketing innovation.

This impacts the building value chain, as it creates the need for tailored services at the building level to manage demand in an efficient and responsive manner, and integrate self-production and storage. The uptake of demand response and power storage is coherent with uptake of related technologies, such as energy management systems, smart meters, smart thermostats, heat pumps and electric vehicles. The integration of electric vehicles in the energy cycle of buildings is advantageous for the energy use of a building as well as the energy flexibility in the grid.

Building automation and other smart devices are interacting more and more with the energy market, but if the large conventional companies are not to cover the demand response segment for the residential market in the near future, other actors will. New market actors capturing value across this value chain, originated in the ICT (e.g. Google, Apple), and electric vehicle (e.g. Tesla) value chains are starting to enter the market. There is an opportunity as well for manufacturers of household appliances and products such as heat pumps, HVAC and white goods to adapt their products to function in this new technological environment.

People are excited by new technologies, but concerns regarding comfort and data privacy need to form an integral part of the innovation process. Behavioural changes will happen faster if there is societal acceptance. Widespread adaptation of renewable and storage technologies, and marketing campaigns, such as the Powerwall campaign by Tesla, largely contribute to this.

While technological innovation will continue to support the transformation and integration of the energy and building sector, policy innovation is needed most urgently now. The ongoing reviews of related European Directives provide many opportunities to create an enabling and transformative regulatory environment. This will result in lower investment costs in the energy system, a lower CO_2 intensity of the energy supply, and a more stable and flexible infrastructure.

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