Briefing
December 2016

Smart appliances and the electrical system

SUMMARY

Smart appliances could help shift demand away from peak periods, which is important for an electricity system that relies on variable renewable energy sources. Most of this move will have to be automated, with smart appliances communicating with the electricity system. However, this is contingent on solving issues regarding the interoperability necessary for coordinating multiple smart appliances and households. It will also require the roll-out of smart meters and dynamic electricity prices, as well as making 'demand response' possible in various energy markets.

While consumers seem to have a positive attitude to smart appliances, they are not willing to change their habits unless they achieve substantial financial savings, and are not inclined to deal with control interfaces that are too complicated. Studies show that they are worried about the reliability, privacy and security of these new technologies.

Use of smart appliances could significantly benefit the electricity system when it comes to matching supply and demand in the grid, short-term balancing of the system, and reducing consumption. It could reduce the need for fossil fuel back-up and be conducive to an increased use of wind power. While the benefits seem to be many, the costs are not always clear. The European Commission recognises the potential of smart appliances and advocates development of smart infrastructure. The European Parliament seems to agree, as long as this benefits the consumer and affords a high level of data and privacy protection.

In this briefing:

EPRS | European Parliamentary Research Service
Author: Nikolina Šajn
Members' Research Service
PE 595.859

Importance of smart appliances

Household appliances that can be programmed or monitored remotely could be an important means to regulate demand for an electricity system which relies on variable renewable energy sources (RES). They could also help the EU reach its climate policy targets, by promoting further integration of renewables, possibly moderating energy demand, and reducing greenhouse gas emissions.

The biggest potential lies in helping to shift electricity demand away from periods when there is a lack of electricity in the system, either because there is no sun or wind to produce it from renewable sources, or because of unexpected system failure. In certain cases smart appliances could more than shift demand, they could also help to lower electricity consumption altogether, for instance if they are programmed to switch off the lights when nobody is in the room or turn off non-essential appliances, such as a radio, if the electricity in the system is scarce. This would help to balance a system that is expected to increasingly rely on renewable energy sources, and would decrease greenhouse gas emissions. Since, for technical reasons, the supply and demand in an electric grid must always be balanced, as electricity generation becomes more variable, either additional back-up generation will be necessary or consumption will also have to become variable – increasing and decreasing according to electricity availability.[1]

Smart homes

A 'smart home' is a home equipped with sensors and a home network that coordinates multiple smart appliances, and electricity produced onsite. Smart homes may also use sensors to lower energy consumption by, for instance, turning off the lights or heating when nobody is at home. Besides optimising electricity consumption, smart homes have other advantages – increased home security through detecting unusual movement in the house, or for assisted living, health, entertainment or communication.

Smart appliances could play an important role in shifting electricity demand in residential buildings, which accounted for about 25 % of final energy consumption in the EU in 2014.[2] This may become even more important as electricity demand is expected to rise over the coming decades, primarily due to electrification of heating (through electric heat pumps) and transport (electric cars), and as buildings turn into 'micro energy hubs' of the future that produce, consume and store energy. Investments in new infrastructure that would accommodate this rise in consumption could partially be avoided by spreading the demand more evenly in time and better coordination with electricity production.

However, to achieve this, consumers would need to be awarded for the inconvenience and the change in their behaviour. This could be done through dynamic electricity prices which would reflect electricity costs in real time, depending on availability in the system (which is not currently the case) and the roll out of smart grids and smart meters, which would provide the price signals and record the consumption. Alternatively, consumers could receive financial compensation from utility companies, distributors or aggregators, for providing services to the system. Currently, in many EU Member States, such service providers are not allowed to participate in energy markets.

Demand shifting in practice

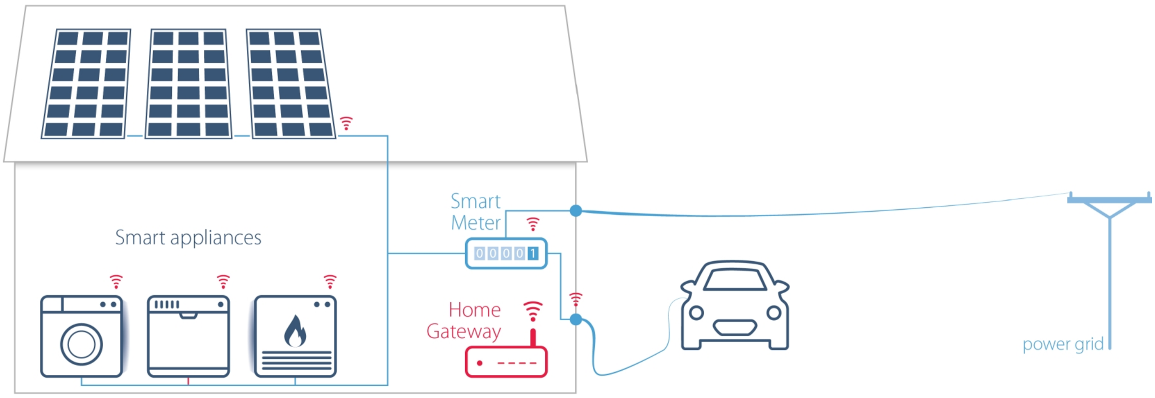
Types of demand shifting

Energy demand shifting can work for 'responsive' or 'flexible' loads, which do not have to be operated at a strictly determined time. There are two possibilities, for example, postponing use of appliances such as dishwashers, washing machines, and tumble dryers, which can be operated on a flexible schedule (at a time convenient to the user), without changing the consumption of energy or the duration needed to perform a task. The second, interruption, can work for appliances such as refrigerators, electric boilers, and heat pumps. These can be either set to function at a lower level, using a heating thermostat to lower temperature for instance, whereby consumption is simply lowered and not shifted to another time. Alternatively, power supply can be interrupted for a limited time during operation (usually for not more than 15 to 30 minutes at a time).[3]

Automation level

Smart appliances can be operated at various levels of automation. Delayed start function is already widely available for many household appliances, enabling users to manually set appliance start times in advance. This is, however, not considered a truly 'smart' function, and there is now an understanding that purely manual operation shifting might not lead to significant shift in demand, as users consider it too cumbersome and are discouraged.[4] More promising is a smart manual function which allows consumers to set the time when the task should be finished on a case-by-case basis, leaving it to the appliance to determine when the optimal time for performing the task would be, depending on the information received from the smart meter. 'Set-and-forget' operation means that consumers are asked for their preferences once, usually during the set up procedure, and the tasks are then performed automatically, unless the user decides to override them. Fully automated operation, for fridges and freezers for instance, would scarcely be noticed by users, and would not allow consumers to modify operations.

Figure 1 – Smart appliances in smart homes



Graphic by EPRS.

Energy management system

Smart operation may require a home gateway/energy management system (EMS), which communicates with the smart meter and all smart appliances simultaneously, receiving information on the real-time prices of electricity, onsite renewable energy production and user preferences, and coordinates the appliances accordingly. Users could, for instance, tell the system by what time they want the dishes to be washed and when and how far they plan to drive their electric vehicle, and the system would calculate the best time to start the dishwasher and charge the electric vehicle.

The home gateway would have no physical link to the electricity system and would not need to be a physical device inside the house, but could be connected to the smart appliances via the internet and allow them to be controlled and programmed remotely. While it is possible that this functionality could be taken over by the smart meter as well, it is still a point of debate whether this is desirable or not.

Interoperability

Some form of appliance coordination is already possible, as many smart appliances come with dedicated apps that enable programming and remote control, but their coordination is possible usually only between appliances made by the same producer, thus limiting consumer choice. To overcome this interoperability issue, the European Commission has provided financial assistance towards creating a language ('reference ontology') for smart appliances. This Smart Appliances Reference (SAREF) ontology became a European standard reference language for energy-related data in 2015. Using the language in microchips in all smart appliances in the EU would allow communication with smart meters and usage coordination depending on electricity prices and user needs. The appliances could also be operated remotely in a large number of households by a third-party, such as an aggregator – electricity system operator, electricity retailer or independent service provider – which would compensate the consumers for supplying flexibility to the electricity system.

Demand response

There are two types of demand response. According to the Commission's Joint Research Centre (JRC), **implicit or price-based demand response** 'incentivises changes in electric consumption patterns by end-use consumers in response to changes in price of electricity over time'. The reward for the end user comes in the form of a lower electricity bill – in Finland or Sweden consumers with dynamically priced tariffs already pay 15 % to 30 % less.[5] **Explicit or incentive-based demand response** is designed 'to induce lower electricity use at times of high market prices or when grid reliability is jeopardised.'[6] Consumers receive direct payments for changing their consumption – in the case of residential consumers, an aggregator would pool demand response from a large number of households and place it on various energy markets (day before, intraday, future markets, balancing, ancillary services or capacity markets). Consumers can simultaneously participate in both implicit and explicit demand response.

Issues facing consumers

User acceptance

While consumers seem to generally have a positive attitude towards smart appliances and shifting of consumption, this acceptance comes with a number of caveats. A 2013 United Kingdom study showed that consumers were willing to have their homes automated, but not to significantly change their habits or experience a reduction in their level of comfort, unless they achieved substantial financial savings. According to the European Smart Domestic Appliances in Sustainable Energy Systems (Smart A) project,[7] if a smart appliance were to cost €25 more than a regular version, users would expect a return on their money in a maximum of three years. On the other hand, they were ready to accept a cost of up to €25 in exchange for increased comfort, safety and ease of operation, without any financial benefits.

User fatigue

Despite a general acceptance of smart appliances, consumers participating in the Linear project, a large study recording the use of smart appliances in real-life conditions, often found the necessary changes to their behaviour too onerous. The project showed that manual shifting of demand in response to dynamic prices did not work in practice: consumers gave up due to the level of intrusion in their daily routines. Study participants equipped with smart appliances were much less likely to experience user fatigue, except for those who experienced technical problems. However, their perseverance was not the same for all appliances: the dropout rate was the largest for electric vehicles, apparently because of an overcomplicated interface. Researchers concluded that to avoid user fatigue, user effort in configuring smart appliances needs to be minimal.

Reliability

Consumers and experts participating in the 2013 United Kingdom study worried about the reliability of smart home systems and possible malfunctions of the network used to carry a signal for switching smart appliances on and off. For instance, users were worried about not being able to turn on the light if the system was down. Experts considered a manual override could minimise that risk. The Smart A study confirmed that consumers want full control and an override option.

Privacy and security

Cyber-attacks on servers or cloud-based services present a serious concern for smart appliances. Such attacks could interrupt normal functioning or expose the user data to unauthorised access. Consumers in the UK study worried, for instance, about loss of privacy, and strangers knowing their daily routines or when they were in the house.[8] Privacy and security concerns are analysed in more detail in an EPRS briefing on the Internet of Things published in May 2015.

Opportunities and challenges for the electricity system

According to the European Commission, the total potential for demand response in the EU is 60 GW, which roughly equals a third of all EU gas fired electricity generation. Demand response could reduce peak generation of electricity in the EU by 10 % and lower consumers' bills by an equal percentage. Other studies estimate that demand response potential could be even higher.[9]

The Smart A project modelled the EU electricity system in 2025, with the expectation that renewable energy sources, mainly wind and solar, would be used to produce 40 % of electricity in the EU. Of the 10 appliances studied, electric heaters and water heaters had the largest flexibility potential.[10] The model showed that smart appliances can help with matching the scheduled supply and demand in the electricity grid (a day ahead), short-term balancing of the system (intraday) and reducing congestion on the distribution (local) level. The study concluded that smart appliances could shift enough peak demand to reduce the need for back-up power plants based on fossil fuel, and would enable the use of more wind energy, which is currently subject to restrictions ('curtailment') during periods of low demand. This could eventually lead to lower electricity prices in general, but only if the suppliers pass on these savings to consumers. The highest benefits were predicted in regions with high shares of variable wind power and low flexibility of power generation, such as nuclear and fossil fuel power plants.

The preliminary results of the 2015 preparatory study on smart appliances: task 6 by the Flemish Institute for Technological Research (VITO) showed that, by 2030, smart appliances could provide €1 710.5 million in savings to system costs through providing day-ahead flexibility per year and €131.49 million through intraday flexibility (this includes smart energy storage, but not smart electric vehicle charging). The study shows that a smart dishwasher could, for instance, create a benefit to the system of €7.53 per year, the benefits of a heat pump would be €14.50, while various types of electric radiators create a benefit of between €9.65 and €77 per year.[11]

Other studies also modelled and verified the flexibility potential of smart appliances: a Low Carbon London (LCL) project showed that 'wet appliances' (washing machines, tumble dryers and dishwashers) offered about 9-13 % demand shifting possibilities if they are centrally managed. A study in the United States tested optimisation of air conditioning, dishwasher and combined washer/dryer use, and showed that in a small neighbourhood of just 40 houses, optimising washer/dryer and dishwasher use could reduce peak load by 3 %, optimising the air conditioning thermostat by 18.8 %, and optimising all three appliances by 25.5 %.[12] However, although peaks were reduced, the consumption of electricity by individual households was the same, and sometimes even increased.

An overall increase in energy consumption is not unusual when smart appliances are used for demand response. For instance, a washing machine waiting for a signal to switch on can spend hours on stand-by, during which time it uses energy.[13] According to the Smart A study, this can increase the electricity consumption of an appliance by 0.1 % to 2 %. On the other hand, if the operation of the washing machine is interrupted after it has heated the water (the most energy-demanding part of the washing cycle), it will have to reheat the water once it is switched back on again, requiring additional energy (this is called the **energy payback effect**). The same applies to switching off other appliances with thermal processes, such as heating or air conditioning. Moreover, smart appliances can cause **secondary peak loads**, as the end of a high price signal triggers a massive switching on of appliances. Such synchronisation can be avoided by centrally controlled aggregated demand-response, which takes into account demand in a whole area and not just an individual household.

The Smart A authors warn that the value of appliances would diminish if Europe had a perfectly interconnected electricity market, in which surpluses in one country could be used to fill gaps in another country. In this case, gross economic benefit of smart appliances in 29 European countries[14] in 2025 would be between €14 and €22 per kW per year. However, the cost of implementation of smart appliances would be around €9 to €15, and perhaps up to €30 per kW per year, which means that in some Member States using smart appliances for demand response might not be cost effective.[15] The question of cost has not yet been widely studied: the Smart A project estimates that the costs for individual households acquiring smart appliances may not be excessive, as most new models of appliances already feature advanced electronics, adding 'smartness' – the ability to communicate to the smart meter and the home gateway – may cost between €1.70 and €3.30 per appliance. However, the costs of advanced communication for the whole system is not yet clear.

In addition, the VITO study warns that the value of flexibility provided by smart household appliances might be overestimated, as it is not yet clear whether it will be more profitable for flexibility demand to be served by industrial demand response or electric vehicles, which were not part of the study. The authors warn that this could, among other factors, depend on the cost of infrastructure and communication technology.

EU policy and views of the European Parliament

EU policy recognises the potential of demand response via smart appliances for reducing consumer bills and creating value for the electricity system. As early as in the 2009 Electricity Directive, demand-side management was identified as a means to boost social and economic cohesion and environmental protection and was to be included in tenders for new capacity, while distribution system operators were obliged to take this into consideration before upgrading or replacing electricity capacity. The 2012 Energy Efficiency Directive required EU Member States to enable demand response participation in balancing markets and ancillary services procurement, in wholesale and retail markets, and to promote access to other energy markets. However, according to the Commission's Joint Research Centre report on demand response status in EU Member States, in 2014 none of the 14 Member States included in the study had fully integrated demand response in national electricity markets and the definitions and rules were not always clear.

Smart appliances were explicitly mentioned in the 2015 energy union strategy, which announced European Commission plans to promote further development of smart appliances and smart grids, and to reward flexible energy use. The Commission also announced it would push for introduction of smart grids and smart meters and try to phase out below cost regulated prices. Smart home appliances and home automation systems were identified as a priority in the research and development component of the energy union.

The November 2016 'Clean Energy for All Europeans' package, which aims to align EU energy policy with the 2030 climate targets, also features smart appliances. The main innovation in the proposal to revise the Energy Performance of Buildings Directive is the introduction of a 'smartness indicator' for buildings, rating buildings' readiness to adapt to the needs of the occupant and of the grid, and to improve performance. The new electricity market design aims to remove the barriers to demand-response services and introduces consumer rights to freely choose an aggregator.

The European Parliament recognises the potential of smart appliances for energy savings and increasing energy efficiency. In its resolution of 26 May 2016 on delivering a new deal for energy consumers, Parliament emphasised the need to facilitate development to enable automation of demand response and alignment with electricity price signals. However, it also emphasised that smart appliances should ensure a high level of data protection, benefit end users, enhance energy savings, and facilitate the involvement of aggregators and energy service companies in markets for energy services and demand management.

In a resolution on the EU strategy on heating and cooling on 13 September 2016, the Parliament called on the European Commission to find a better way to integrate smart technologies in EU legislation, to ensure smart appliance, connected home and smart building interconnectivity with smart grids. It emphasised the importance of home automation and smart heating control and called for the promotion of such solutions in the renovation of existing buildings.

However, in a resolution on the renewable energy progress report of 23 June 2016, the Parliament warned that demand response should not create an additional burden or increased costs for citizens and stressed that participation in demand response and dynamic pricing should always be on a strictly voluntary basis.

Main references

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Endnotes

1 For more details on electricity grids, see EPRS briefing on Understanding Electricity Markets in the EU, November 2016.

2 Data on energy consumption of household appliances are not available. However it is estimated that in 2009, appliances accounted for 10 % of total annual energy consumption in the United Kingdom. See: V. Silva, V. Stanojevic, M. Aunedi, D. Pudjianto, G. Strbac, Smart domestic appliances as enabling technology for demand-side integration: modelling, values and drivers, in T. Jamasb, M.G. Pollitt (Eds.), The Future of Electricity Demand: Customers, Citizens and Loads, 2011.

3 Washing machines and dishwashers can also be interrupted, but because they use a lot of energy at the beginning of their cycle to heat the water, interrupting them may not be beneficial, as they would need to reheat the water when they are restarted.

4 The result of the Linear project, which recorded the behaviour of 240 families in the Belgian Flemish region over 18 months, and their usage of both appliances which could be postponed (washing machines, tumble dryers and dishwashers) and those that could be interrupted (hot water boilers and electric vehicle chargers).

5 The bills of customers with non-flexible contracts were 50% higher in 2012 than those with a flexible contract. See Delivering a New Deal for Energy Consumers, p. 5.

6 P. Bertoldi, P. Zancanella, B. Boza-Kiss, Demand Response Status in EU Member States, Joint Research Centre, Ispra, 2016, p. 2.

7 The European smart domestic appliances in sustainable energy systems project (Smart-A) assesses the potential synergies from coordinating the energy demand of domestic appliances with the generation of electricity and heat from renewable energies or cogeneration with other load management requirements in electricity networks. The project is supported by the European Commission through the Intelligent Energy Europe programme.

8 It is worth noting that participants in the Smart A projects from Austria, Germany, Italy, Slovenia, and the United Kingdom tended to accept the collection and processing of data about their usage of appliances. The authors suggest that this may be because many are now used to such data collection, for instance by retailers.

9 The Smart Energy Demand Coalition quotes a study showing that the potential size for explicit demand response could be 14 % of EU peak demand, while a United Kingdom study showed that the manufacturing sector, hospitals and the services sector could reduce peak demand by 16 %.

10 The study also included refrigerators, freezers, dishwashers, ovens and stoves, washing machines and tumble dryers, air conditioners and circulation pumps for heating systems.

11 Table 10 on p. 19 shows the preliminary results of the study, which are expected to be slightly revised in the final version. The calculations take into account the total cost of electricity production, including greenhouse gas emissions. An older study, part of the 2009 Smart A project, estimated that, by 2025 in regions with moderate flexibility and 25 % wind power, a dishwasher could bring a benefit of €90 over its 12 year lifetime; a washing machine would bring half of these savings because it is more difficult to shift its usage; while a combined washer and dryer could bring benefit of up to €200 over 10 years.

12 It also showed the advantages of 'pre-cooling' houses throughout the day, so that they use less electricity at peak hours.

13 This has been significantly reduced by the EU Standby Regulation. Nevertheless, according to the International Energy Agency, these networked appliances account for 6 % of global electricity consumption.

14 The study included the then EU27 Member States, Norway and Switzerland.

15 See Table 11, p. 38.

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