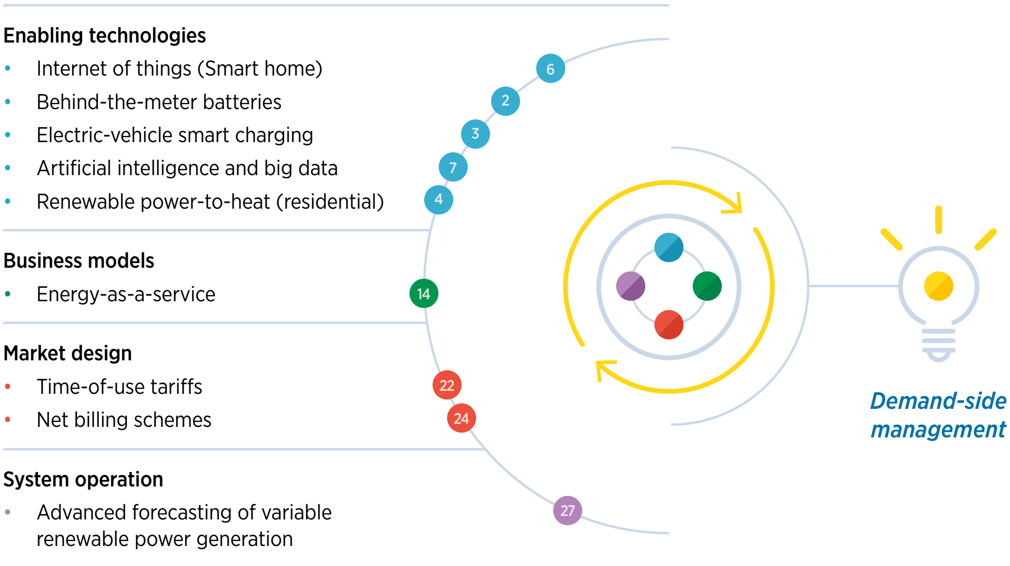
SOLUTION VII

Demand-side management

Figure: Synergies between innovations for enabling demand-side management



Thanks to **enabling technologies**, automation is one of the most important requirements for demand response and demand-side management, without which customers could not respond to price signals in real time. Digital technologies are emerging in smart homes to facilitate demand-side management. The Internet of Things connects devices such as local battery storage, rooftop solar PV, home appliances and smart meters through the Internet, enabling information gathering and exchange.

Internet of Things is basically composed by digitisation of assets, collection of data about the assets and computational algorithms to control the system formed by the interconnected assets. Cloud-based control systems would enable the management of these devices. Computational algorithms, used to control the system, might be replaced by artificial intelligence. At its core, artificial intelligence is a series of systems that acts intelligently, is able to recognise patterns, draws inferences and makes decisions using its own cognitive judgment, the way humans do. *(Key innovations: Internet of Things; Artificial intelligence and big data)*

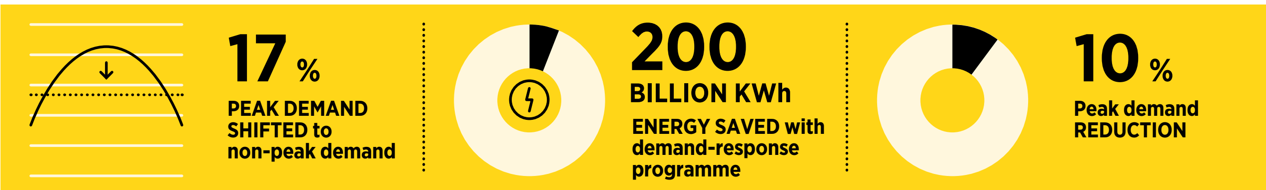
In terms of **market design**, price signals are needed for smart houses to not only increase their energy efficiency, but also to represent a flexibility source for the system. Time-of-use tariffs could be designed to incentivise consumers to shift loads during specific time intervals to support the system and the integration of a high share of VRE. This will allow an increase in consumption when renewable energy generation is available, and a decrease in consumption when there are generation constraints in the system. This has the potential to substantially reduce renewable energy curtailment and improve the system's reliability and predictability.

With real-time pricing, even shorter-term variations in renewable energy output can be balanced with demand response. Under time-of-use tariffs, customers have the choice to adjust their electricity consumption to save on their energy expenses. Automated response is more customer friendly and efficient. In a smart home with rooftop solar PV that can also inject electricity into the grid, a net billing mechanism in place would properly remunerate the renewable energy injected. Under net billing mechanisms, the balance is determined not based on the number of kWh, but on the value of the kWh consumed or injected into the grid. The invoice issued by the supplier is based on the value of the withdrawn energy, which is reduced by the value of the injected energy.

By making prosumers responsible for their interactions with the grid, the integration of VRE generation into the grid is facilitated. Advanced tools to forecast renewable energy generation would help to decrease uncertainty. *(Key innovations: Time-of-use tariffs; Net billing schemes; Advanced forecasting of variable renewable power generation)*

- **New business models** have emerged with digitalisation at the consumer's end. Energy as a service (EaaS) is an innovative business model where a service provider offers various energy-related services rather than only supplying electricity (*i.e.*, kWh). Using automatic control systems, distributed energy resources can provide reactive power support for voltage control. The thermostatically controlled demand can be altered in such a way that the set points are adjusted according to the frequency.

Energy service providers can use remotely controlled intelligent devices to manage consumption and reduce the load during peak demand hours, without compromising customer comfort. Smart home solutions can be bundled as an integrated solution that includes monitoring, automation, the controlling of energy consumption, home safety and home intelligence. A recent survey indicates that the number of "connected homes[9]" or smart homes grew from 17 million to 29 million in the three years from 2015 to 2017, implying a compound annual growth rate of 31% (McKinsey, 2017). *(Key innovation: Energy-as-a-service)*



Impact on demand reduction:

- **17% of the peak demand shifted to non-peak hours through time-of-use tariffs in Sweden.**

Electricity consumption during peak hours declined from 23% to 19% of total electricity demand in a pilot project that used price signals for demand response in Sweden; 17% of the peak demand was therefore shifted to non-peak hours (WEF, 2017).

- **5% of total electricity sales (around 200 billion kWh) was saved during a demand-response programme in the US in 2015.**

A 1% reduction in electricity sales for a utility means on average a 0.66% reduction in peak demand for that utility (Nadel, 2017) .

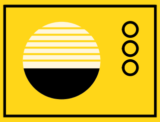
- **Utilities' peak demand could be reduced by 10% on average using demand response.**

The American Council for an Energy-Efficient Economy (ACEEE) has estimated that demand-response programmes can be used to reduce peak demand by 10% or more (Nadel, 2017).

- **A Google data centre using artificial intelligence experienced a 40% reduction in demand used in cooling.**

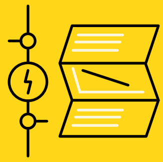
Google's DeepMind AI reduced the energy used for cooling at one of the company's data centres by 40% (a 15% overall reduction in power usage), using only historical data collected from censors and applying a machine-learning algorithm to predict the future temperature and pressure of the data centre and to optimise efficiency (Evans and Gao, 2016).

9 A "connected home" is networked to enable the interconnection and interoperability of multiple devices, services and applications, ranging from communications and entertainment to health care, security and home automation.



40% DEMAND REDUCTION for cooling using AI

15% SAVINGS on the electricity bill with time-of-use tariffs



40% SAVINGS using AI for demand management

Impact on energy costs for consumers:

- **15% savings on utility bill with time-of-use tariffs for 350 households.**

Con Edison's Community Power pilot project would give 350 New York City Housing Authority households access to solar energy for a discounted price. The consumers managed to save 15% on their electricity bills, or around USD 80 (Con Edison, 2018).

- **Up to 40% savings on utility bill using artificial intelligence for demand management.**

BeeBryte, a France- and Singapore-based "software-as-a-service" (SaaS) company, provides cloud-based intelligence software that can monitor real-time load in large commercial and industrial facilities. Using artificial intelligence for weather forecast, occupancy, usage and energy price signals, the software can automatically switch loads such as HVAC systems to battery storage based on time-of-use charges and delivers up to 40% savings in utility bills (BeeBryte, n.d.).

IMPLEMENTED SOLUTION

Reducing renewable energy curtailment – reverse demand-response programme in Arizona

The Arizona Public Service Company (APS), a utility in the US, experiences demand peaks in summer and mild temperatures with lower demand through the remaining three seasons. As temperatures increase in the summer months, air conditioners represent the main load, which is a good match for solar PV. However, with more moderate temperatures during the remaining nine months of the year, the utility has excess solar PV electricity that often remains unutilised. During some time intervals in the daytime, electricity prices turn negative on account of higher solar generation from the distributed resources. A strategy was needed for load shifting on a daily basis to absorb the excess generation from the renewable energy into the grid.

APS recently proposed a new programme that aims to reduce the need to curtail solar energy during periods of negative pricing. Instead of curtailing renewable production, APS will pay customers to use this energy in order to keep the renewables online and smoothen the load curve. This will be similar to load shifting, but because it is less predictable relative to on-peak/off-peak price arbitrage (due to the intermittency of the renewables), the APS programme will be specific to dispatchable non-essential loads. APS's plan includes incentives for smart thermostats, EV charging infrastructure, energy storage and water heater timers, along with a new "reverse demand-response" product that aims to balance system load with excess renewable generation. For example, EVs with smart charging could off-take the free energy when the reverse demand response is activated. During these times, smart appliances (*e.g.*, dishwashers, washing machines, dryers, etc.) can also be run.

APS's reverse demand response helps to avoid renewables curtailment while also creating a value for the utility's customers.

Finnish dynamic pricing structure and smart homes

In Finland, consumers have an option to choose a dynamic pricing tariff structure for electricity. Retail suppliers offer dynamic pricing by choice (without regulation). The price is determined based on the Nord Pool spot price for the price area of Finland. Customers that choose a dynamic pricing tariff structure pay the hourly price, the retailer's premium and a monthly fixed fee to the retailer that they chose to contract with.

By the end of 2017 around 9% (about 340 000) of customers had opted for this tariff structure (Finish Energy Authority, 2018) (Eurelectric, 2017), which allowed them to check electricity prices for each hour of the succeeding day from the chosen retailer's website. The prices are published based on the spot market timetable. Therefore, the prices for the next day (24 hours), starting from midnight, are finalised at around 2 p.m. The price that the customer pays for a particular time slot would depend on the time of consumption. The customer, like all the other consumers in Finland, requires an hourly metering that he/she can see, one day after the delivery, on the web portal or app of the local distribution system operator.

With the technology available today, it is possible to automatically optimise, for example, lighting, heating, ventilation and the use of white goods according to weather conditions and market prices. Some retailers offer price-optimised heating hours, depending on weather conditions and the actual heating capacity. This enables the current heating system to operate efficiently and helps save up to 15% of heating expenses (Eurelectric, 2017).

Flex PowerPlay – home automation in Australia for solar self-consumption

Smart buildings are ultimately all about the energy used at the right time in the right place. Flex PowerPlay, a smart home energy platform launched in 2017 in Australia consists of three elements: solar panels, a home battery and a monitoring system. The Energy App allows users to simply switch between appliances and automatically control power loads, helping control energy and its costs. Optimisation solutions like this will be essential for users to get the most out of their solar system and reduce electricity bills.

Users can monitor their power generation and use it in real time on a smartphone, laptop or tablet. PowerPlay, working with smart technology-enabled appliances, can be programmed to turn the lights on when darkness falls and off again when daylight returns. Users also can remotely control the air conditioner, television and sound systems. The platform not only shows the exact amount of real-time energy generation, but also allows consumers to automatically optimise the consumption.

Other case studies: Energy as a service for demand-side management

Con Ed, a utility in New York, offers a rebate of USD 85 to customers for enrolling in its Demand Response programme. The customers allow the utility to adjust their thermostat for a maximum of 10 times each year (Con Edison, 2016).

PassivSystems, in the UK, provides home energy monitoring and energy management solutions by integrating home technologies (*e.g.*, storage heaters, heat pumps) with the Passiv platform and back-end systems in an Internet-connected solution. It demonstrates that the energy usage in homes could be managed on an aggregated level in response to various energy tariffs and demand-side incentives provided by the grid and network operators (DECC, n.d.).

Similarly, STEM, a US-based energy services provider, helps commercial and industrial customers reduce their energy bills by using the energy stored in their batteries during periods of peak demand. The company combines the battery storage with a cloud-based analytics system to identify the best time to draw energy from the battery storage (Colthorpe, 2017). STEM uses artificial intelligence-enabled technology to maintain a consistent level of energy usage, thus helping businesses control their demand charges (Pickerel, 2018).

"Battery as a service" is another variation of the EaaS business model, which provides storage systems for customers to store energy during periods of low demand and to draw from that stored energy during periods of peak demand. For instance, the European energy service provider E.ON has developed a Solar Cloud for solar PV owners to store the surplus energy supply through a cloud solution. This virtual electricity account can be accessed not only for energy demand at home, but also in other places. The key advantage of power clouds is that consumers do not have to invest in a physical battery. Customers can also save on their energy bills by avoiding peak-use charges (E.ON, 2018). In 2018, in the German market alone, there were more than 1.6 million operators of solar systems. According to E.ON, and based on data from the Sunroof co-operation between E.ON and Google, another 10 million roofs in Germany are suitable for installing PV systems. Such services therefore have great market potential.

SUMMARY TABLE: BENEFITS AND COSTS OF DEMAND-SIDE MANAGEMENT

Demand-side management	Low	Moderate	High	Very high
BENEFIT				
Potential increase in system flexibility				
Flexibility needs addressed	from minutes to days			
COST and COMPLEXITY				
Technology and infrastructure costs	smart meters, ICT			
Required changes in the regulation framework	price signals to consumers			
Required changes in the role of actors	active consumers - automation as facilitator			
Other challenges	• Consumers participation and guaranteed privacy			

This document is extracted from a longer report:

IRENA (2019), ***Innovation landscape for a renewable-powered future: Solutions to integrate variable renewables.*** International Renewable Energy Agency, Abu Dhabi (**ISBN 978-92-9260-111-9**).

The full report and related materials are available on the IRENA website (**www.irena.org**).