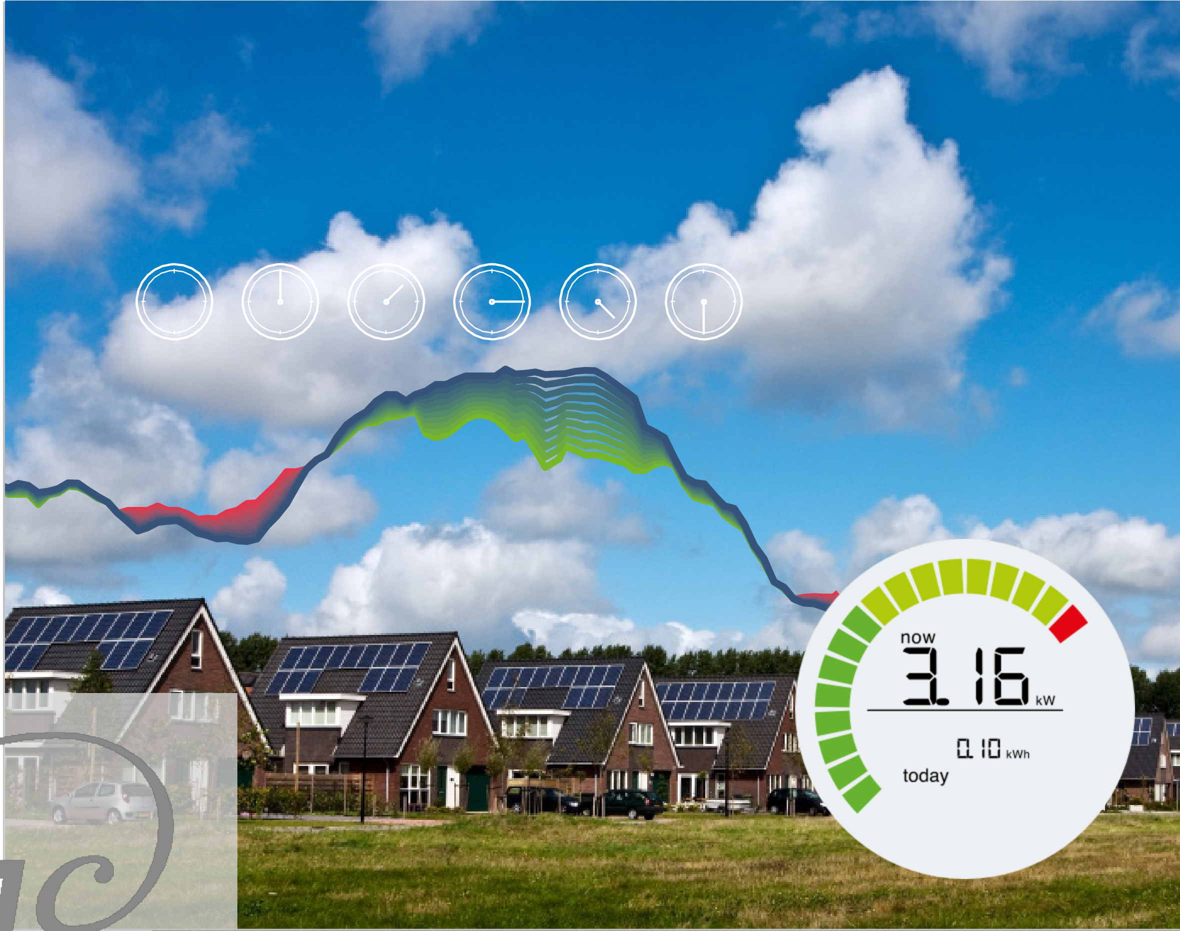

international risk governance council

REPORT

DEMAND-SIDE FLEXIBILITY FOR ENERGY TRANSITIONS

Ensuring the competitive development of demand response options

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Acronyms

BDR	Behavioural Demand Response
BRP	Balance Responsible Party
CHP	Combined Heat and Power
C&I	Commercial and Industrial
CPP	Critical Peak Pricing
DLC	Direct Load Control
DR	Demand Response
DRMS	Demand Response Management Solutions
DSM	Demand-Side Management
DSO	Distribution System Operator
EE	Energy Efficiency
EMCS	Energy Management Control System
EM&V	Evaluation, Measurement and Verification
FERC	Federal Energy Regulatory Commission
HEMS	Home Energy Management System
ICT	Information and Communication Technology
IHD	In-Home Display
IRES	Intermittent Renewable Energy Sources
ISO	Independent Service Operator
MSP	Multi-Sided Platform
PTR	Peak Time Rebate
RDR	Residential Demand Response
RTP	Real-Time Pricing
TSO	Transmission System Operator
TOU	Time of Use

TSO: In the electrical power business, Transmission System Operators (TSOs) transmit electrical power from generation plants over the electrical grid to regional or local electricity distribution operators.

DSO: Distribution System Operators (DSOs) operate, ensure the maintenance of and, if necessary, develop the distribution system in a given area and, where applicable, its interconnections with other systems

BRP: A Balance Responsible Party (BRP) is responsible for ensuring that the supply of energy corresponds to the anticipated consumption of energy in its balance area during a given time period and financially regulates for any imbalance that arises

Aggregator: Demand response aggregators are new entities in the electricity market that act as brokers between end-customers and the utility operator. They combine the electricity demand of two or more customers into a single purchasing unit to negotiate with electricity providers. They may be responsible for installing the relevant technology (e.g. smart meters) at end-user premises to be able to manage electricity demand in their portfolio. They receive monetary compensation from utility operators for doing so and reward end-users for the provision of demand flexibility.

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PREFACE

IRGC's project work on **energy transitions** is first motivated by the fact that large-scale transitions or transformation of energy systems are needed in order to address long-term risks that currently exist in most energy systems, albeit with variations across regions. These transformations will take place over the next several decades and redefine risks and opportunities within the energy and other sectors and for a wide range of stakeholders. Although the objectives of energy transitions, such as the provision of secure, reliable, affordable and low-carbon electricity supply are widely accepted, energy transitions are accompanied by a number of **uncertainties and risks**, among which destabilisations of existing markets and their actors. If not adequately managed, these risks may lead to deep perturbation in the economy and society.

Second, the focus of IRGC's work on '**demand anticipation and consumer behaviour**' is informed by the realisation that policies and strategies have traditionally focused on the supply side of energy systems while behaviour and end-use demands have received less attention. In this project, IRGC evaluates opportunities, risks and governance regimes, with a view to providing guidelines for effective governance of the demand side of energy transitions.

Third, IRGC and the Energy Center of the Ecole Polytechnique Fédérale de Lausanne (EPFL) recognised that various countries in the world consider or implement '**demand response**' **as activities to facilitate the transition towards decarbonised energy systems**. Those are characterised by an increased share of intermittent renewable energy and increased electrification, and require new forms of **power system flexibility** to be sustainable**.** This calls for a paradigm shift in the power sector, particularly that demand profiles increasingly follow electricity generation rather than the other way round. Demand response (or demand-side response), which involves **temporary changes in electricity consumption, typically in response to price signals or other financial incentives, or in reaction to grid conditions**, is expected to cost-effectively contribute to the much needed power system flexibility, and help improve the efficiency of generation of transmission networks.

However, while demand response has gained traction among diverse stakeholders in the electricity industry in some countries, **widespread uptake of demand response, especially by consumers and load aggregators, remains slow due to uncertainties and various types of barriers, whether economic, technological, social or regulatory**. Adopting a risk governance approach to demand response deployment would be useful to unlock certain barriers and assess to what extent demand response can reliably contribute to power system flexibility.

On September 10 – 11 2015, IRGC and the EPFL Energy Center organised an international conference and an expert workshop[1] on "Demand Response: Opportunities and Challenges in the Context of Energy Transitions" to help shed light on:

- The merits and limitations of demand response for power system flexibility
- The risks and opportunities or different approaches to demand response
- The key enablers and barriers for realising demand response potential, encompassing end-user behaviour, business models, market design and regulation.

The present report was initially prepared as a background paper to the workshop. It provides an overview of the current debates about demand response development. Its main purpose is not to provide policy recommendations. It focuses primarily on Europe, with some comparisons to the United States.

[1] A brief description of the conference and workshop is provided in the Appendix

SUMMARY

‘Demand response’ includes strategies that involve end-use customers adapting or altering their electricity demand in response to grid conditions (e.g. system emergencies) or in response to market prices. It is increasingly viewed by many stakeholders as a multi-purpose power-system resource that enhances the energy system’s capacity to cope with increasing demand (e.g. due to electrification of transportation), rising costs of conventional transmission and distribution grids, and increasing share of intermittent renewable energy (solar and wind). Specifically, demand response is a set of cooperative strategies involving utilities, their customers and, increasingly, third-party energy service providers to dynamically balance demand and supply in the context of transitions towards low-carbon and efficient power systems. Demand response has the key advantage that it can help policymakers achieve energy-related environmental goals, energy affordability and energy security simultaneously.

Demand response *per se* is not new: it has been deployed for several decades now to shave peak demand, but it is gaining new impetus with the increasing share of variable renewable generation as well as other technological developments. These technological enablers include Advanced Metering Infrastructure, load control devices, Energy Management Control Systems, advanced information and communication technologies, along with supply-side innovations such as decentralised (or distributed) generation and decentralised storage.

BENEFITS | These technological developments are creating a paradigm shift in power systems, enabling demand response to deliver a wide array of benefits: (i) enhanced system reliability in terms of both power and frequency regulation, (ii) economic efficiency (optimised investment in generation capacity, transmission and distribution infrastructure, enhanced market competition and potentially lower electricity bill), and (iii) environmental benefits both direct (as in the case of load shedding/curtailment that is not replaced by carbon-intensive back-up generation) and indirect (when load is shifted away from carbon intensive peak generation to low-carbon baseload).

RISKS | There are however numerous challenges associated with demand response development. From a long-term planning perspective, demand response should not displace investment in infrastructure that would be needed for cost-effective power grid operation and that have a long lead time. Operational risks such as intermittent renewable resource curtailment in view of storage capacity limit of some demand response products should be factored in. Likewise, the market risks such as price volatility and volume risks (unscheduled load curtailment) must be mitigated.

In the context of energy transitions, failure to deploy demand response or its poor implementation would result in new risks for various actors, including utilities and consumers. That said, energy transitions, by definition, will create new opportunities for some players and destabilise others. Deploying demand response effectively remains challenging due to technical, market, regulatory and behavioural barriers. These have to be addressed alongside business model innovation to generate and extract value from demand response.

POTENTIAL | To assess realisable potential, either bottom-up or top-down approaches are used depending on the scale and scope of demand response to be deployed. Bottom-up approaches are more appropriate for industrial processes than for regional or nation-wide assessment of demand response need/availability. Assessing the technical potential alone is not sufficient; the economic potential should also be assessed and proper attention given to the merits and limitations of assessment methods.

Market conditions will affect the economic potential of demand response while consumer behaviour (e.g. responsiveness) and physical properties of demand response resource (e.g. storage capacity and hysteresis) will influence the capacity value of demand response (i.e. the amount of demand response available when called

for). Aggregators deal with the non-availability risk by pooling different resources and use statistical/probabilistic forecasts to estimate the amount they can commit to the market. Finally, depending on the type of demand response resource, appropriate baseline measurement and verification must be established to avoid gaming risks.

CONSUMER ENGAGEMENT | Relatedly, another challenge for successful deployment of demand response is consumer engagement, the capacity value of demand response depends on the willingness and ability of consumers to curtail load when asked, including the willingness to accept compensation for a change in energy service as in the case of direct load control. Typically, the value of demand response for commercial and industrial (C&I) consumers is much larger than for individual residential consumers. But from a system level perspective, the aggregation of small residential loads can provide significant demand response resources. Today, there are many service providers that are working together with C&I consumers to optimise their processes for demand response and reduce energy-related operating expenditures. For residential consumers, an incremental approach is recommended, whereby consumers are educated about the benefits of demand response and provided with implicit incentives in the form of neighbour comparison. Dynamic pricing and direct load control are only offered at later stages.

The long history of demand response in certain countries, particularly in the United States, suggests that there is a strong business case for demand response. However, European demand response to deal with the volatility and uncertainty of wind and power, i.e. demand response for ancillary services, is very different. Often it requires an investment in infrastructure such as data hubs and smart meters that are effectively common pool resources. As a result, platform business models are emerging in Europe but in which the apportionment of cost and benefits among different exchange partners remains a challenge.

MARKET DESIGN | Market design features, particularly contractual, relational and market-entry/participation rules, impact the way business models evolve, including opportunities for value capture by relevant stakeholders along the demand response value chain. Today, the consensus is that market design in most countries is not conducive to demand response deployment. Critical market barriers include minimum bid requirements, regulated retail prices/lack of dynamic pricing and the absence of mutual links between wholesale and retail markets that stymie widespread demand response investment and engagement. The market design has to be reviewed to open up pathways for demand response development.

POLICY AND REGULATION | Cost-effective demand response strategies must be supported by adequate policy and regulation, to ensure their competitive development in power systems that are undergoing transformations. Regulation regarding minimum quantities, qualification protocols, distortionary incentives such as coal/gas subsidies and feed-in tariffs should be reviewed to reduce regulatory barriers to demand response, as well as barriers to power system optimisation. Regulation is however needed where markets fail, e.g. where the transaction costs are too high and where demand response development are stymied by uncertainties inherent in transitions. Policymakers can and should provide, at the right time, some roadmaps that would guide investment demand response as a flexibility option, and to reduce (policy) risk premia of investors.

CONTEXTUAL DEVELOPMENT |Countries that are now contemplating the development of demand response can adopt the best practices identified by other countries and also learn from their mistakes. Demand response development has to be tailored to country-specific power system needs taking into account potential cross-border energy exchanges as a power-system resource. Investment planning should identify the optimal share for demand response in a mix of flexibility options for different scenarios.

The cost-effectiveness of actual demand response deployment can be enhanced by putting in place relevant evaluation, measurement and verification schemes, targeting specific consumer segments and designing appropriate contracts, and reducing market and regulatory barriers to allow different business models to evolve and both generate and capture value from demand response provision. While there may be convergence in technical, economic and regulatory solutions, the pathways for demand response development is likely to be very country- and sector-specific.

1.
INTRODUCTION

Business-as-usual scenarios of energy supply and consumption are deemed to be unsustainable economically, environmentally, and socially. In Europe, this has led the European Union to set ambitious energy and emission targets for 2020, 2030 and 2050. As a result, the long-held tenets of the electricity sector are being re-written with intermittent energy sources quickly becoming mainstream. Not only has the current high penetration of solar photovoltaic systems due subsidies and feed-in tariffs caught stakeholders by surprise, but also wind and rooftop solar power have, on average, reached grid parity much earlier than expected thanks to rapid cost decline, displacing thermal loads. The outcome is a power system that is not fit-for-purpose: balancing demand and supply loads has become more challenging because of the volatile and uncertain availability of wind and solar power and the unavailability (or limited availability) of flexible and low-carbon non-baseload generation plants, as well as storage, grid limitations, and inflexible demand. Increasing electrification, as a result of decarbonisation, can exacerbate this imbalance if loads are not properly managed.

Flexibility for balancing power supply and demand is traditionally provided mainly by the generation side. Specifically, to meet peak demand, utilities typically invest either in extra power-generation capacity or in large storage capacity, such as hydro pumped storage. The transition to a low-carbon society, however, increases the need for a full spectrum of power system flexibility, e.g. from grid reinforcement (including super grid development) to dispatchable generation, from balancing markets to new wholesale electricity arrangements, and from flexible generation to demand response (DR) (see Figure 1). A more flexible future electric power system is likely to include conventional generation, intermittent renewable generation (e.g. wind and solar), additional storage, price-responsive load, and distributed energy resources that **rely more heavily on the ability**

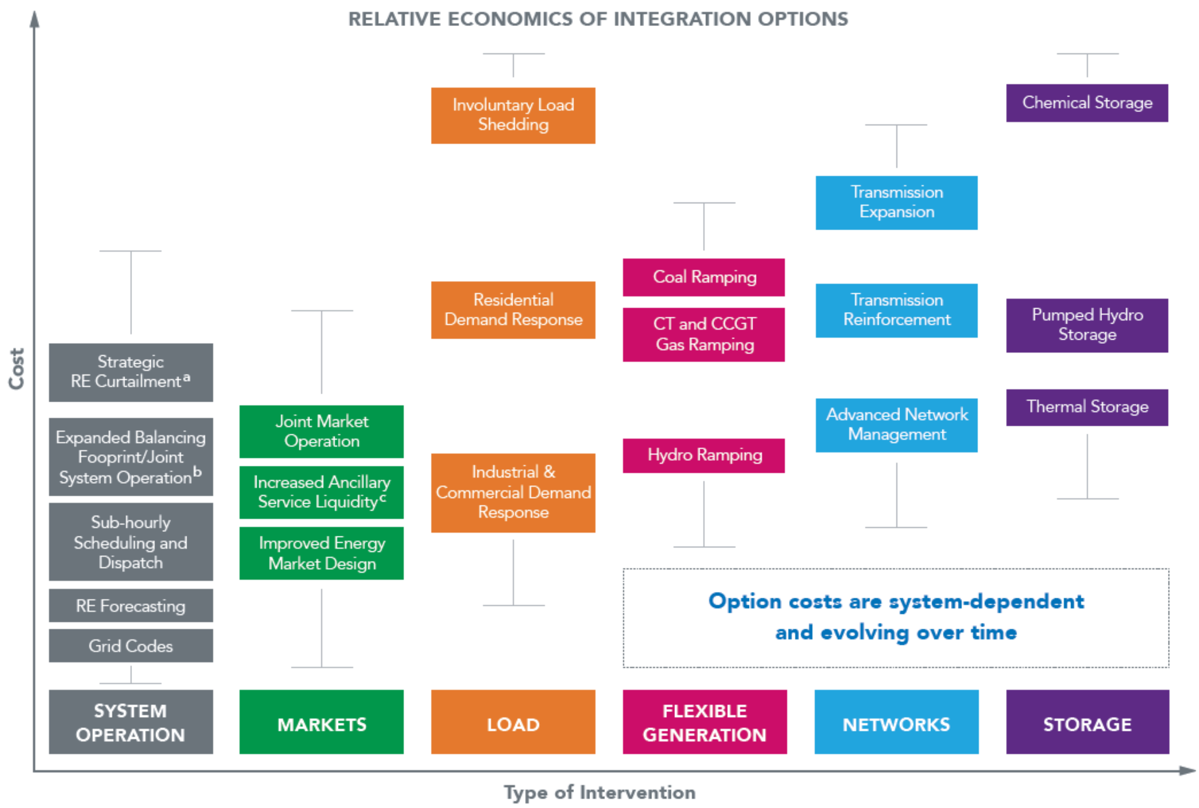


Figure 1: Relative economics of integration options. Source: NREL (2014)
RE: Renewable Energy; CT: Combustion Turbine; CCGT: Combined Cycle Gas Turbine

of customer loads to respond to fluctuations in supply.

Demand response (DR) is a form of demand-side flexibility that requires that end-users adjust consumption in response to fluctuating supply, rather than the other way round (The Economist, 2015). It is the greenest, fastest and most capital-efficient among all the flexibilisation options (see Figure 2). **DR includes a set of strategies that encompass temporary shifts in electricity consumption loads typically in response to price signals or other financial incentives, or in reaction to grid conditions (e.g. system emergencies)**. Consumers participating in demand response programmes, for example through price signals or incentive payments, agree to modify their energy demand patterns by (i) reducing overall energy use (demand curtailment) in response to high prices or system conditions, or (ii) shifting loads from peak to off-peak periods, or (iii) increasing demand when supply is abundant (including through local storage).

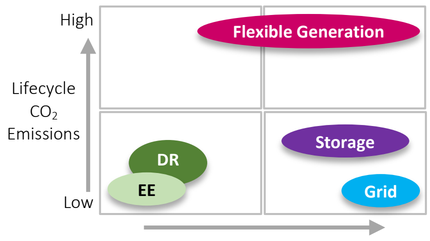


Figure 2: Comparison of five flexibility pillars.
Source: Entelios Analysis; Adapted from http://www.addressfp7.org/ws2013/afternoon/03b-Entelios_ADDRESS.pdf

As a result of its evolution as described in Section 1.1, DR is becoming an important tool to dynamically balance power demand and supply, including frequency regulation. Today, various countries in the world consider or implement DR. For example, it is among California's top energy priorities to facilitate the state's aggressive policies for large-scale deployment of variable generation (wind and power)[2]. In Switzerland, a pilot project, "Flexlast," was carried out in 2013 to assess the potential of DR for integrating variable generation (wind and solar; see Box 1). Subsequently, the Distribution System Operator (DSO) has partnered with a major DR service provider to provide a range of DR products. In effect, DR resources can provide numerous power system benefits (see Section 1.2), and trigger a shift in the power sector away from a traditional consumption-driven paradigm.

The deployment of these resources, including policies and regulation that oversee it, should however be considered together with other developments so as to minimise overall power system risks (see Section 1.3) and to facilitate energy transitions towards to low-carbon power systems.

1.1. Demand response development: past, present and future

DR harkens back to the 1970s in the US when it started to be implemented to prevent blackouts and brownouts.

- **DR 1.0**: DR has thereafter been deployed for **peak-load shedding in order to reduce peak capacity generation requirements**
- **DR 2.0:** DR is now moving towards **load shaping through enhanced automation**
- **DR 3.0:**, as smart grids develop,DR goes towards **2-way communications and intelligent load management** to the distribution network, thus moving closer to real-time and full interaction with end-users[3].

Advanced forms of DR are currently given much attention because of increased reliance on intermittent renewable energy, and because of the arrival of affordable and distributed energy storage (electric vehicle, home batteries, thermal energy storage). Other DR-enabling technologies include heat pumps, load control, EMCS, smart appliances and micro-CHP. In parallel, advances in information and communication technology (ICT) enable the development of smart technology, such as smart meters and advanced metering infrastructure, which hold the potential to change the way consumers interact with electricity providers and, eventually, the way they consume power. Low ICT costs also create new opportunities for utilities to better serve consumers by tapping into advanced data analytics.

[2] See California Public Utilities Commission's stance on demand response at http://www.cpuc.ca.gov/PUC/energy/Demand+Response/
[3] See http://www.elp.com/articles/print/volume-92/issue-2/sections/energy-efficiency-demand-response/demand-response-optimization-and-optionality.html

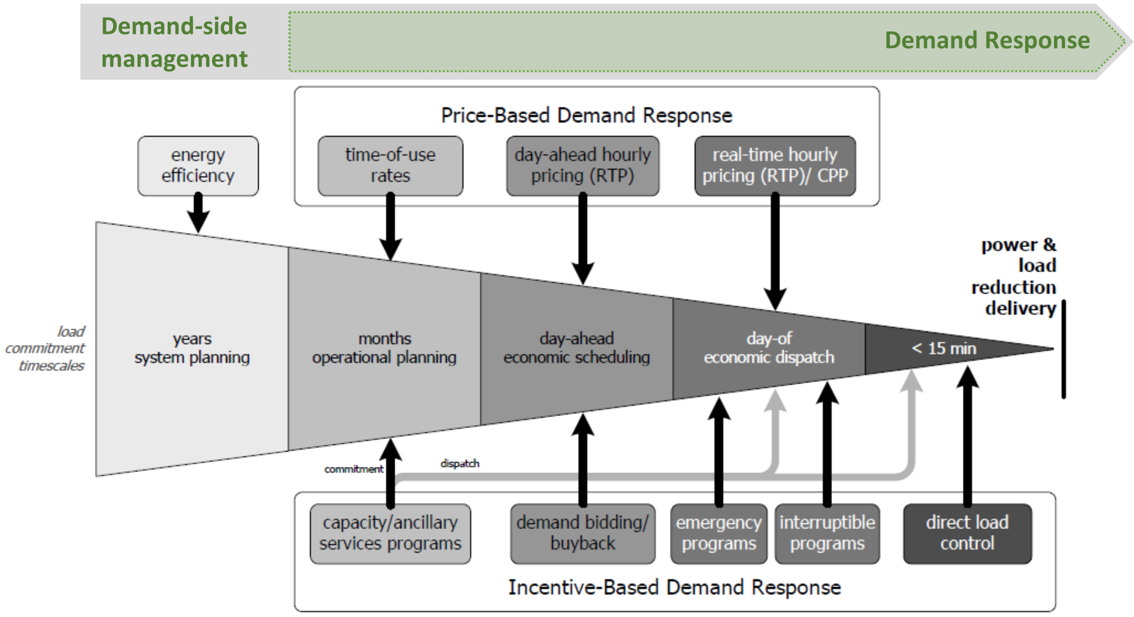


Figure 3: The time spectrum of different demand-side management programmes. Source DOE (2006)

As a result, there is a range of demand response options (see Figure 3)[4] that are categorised as *price-bas*ed (aka. implicit DR) and *incentive-based* options (aka. explicit or volume-based DR). These different options participate in different electricity markets (energy, balancing, reserve, capacity) at different time scales and contribute different amounts of energy resources. The combination of service type (capacity, energy, reserve and regulation), minimum eligible resource size (100 kW, 500 kW, 1 MW, 5 MW, etc.), aggregation possibility and primary driver (economic, reliability, balancing) generate a continuum of DR products.

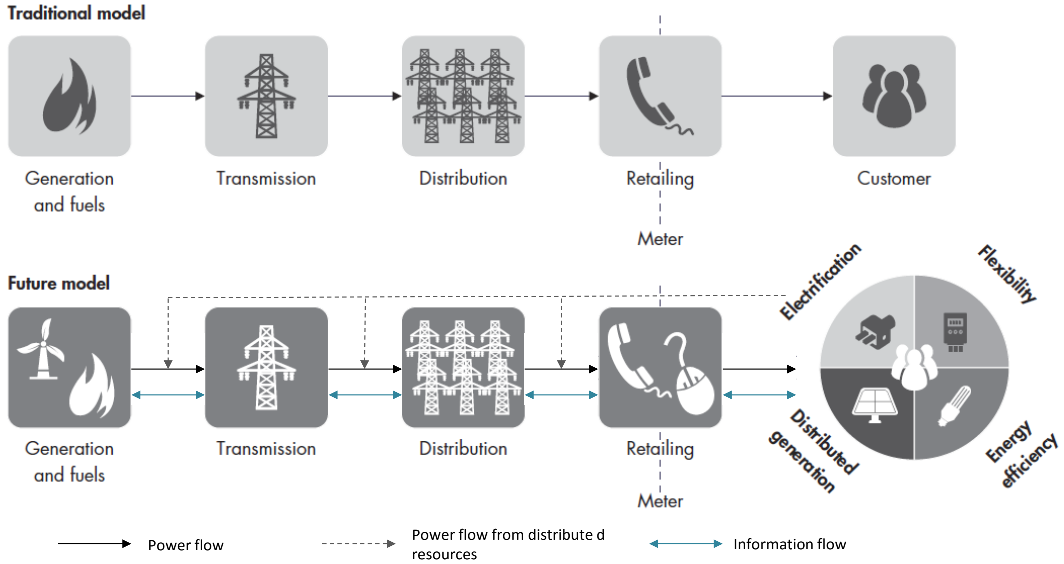


Figure 4: Traditional and emerging electricity value chain. Source: Adapted from Bain (2015)

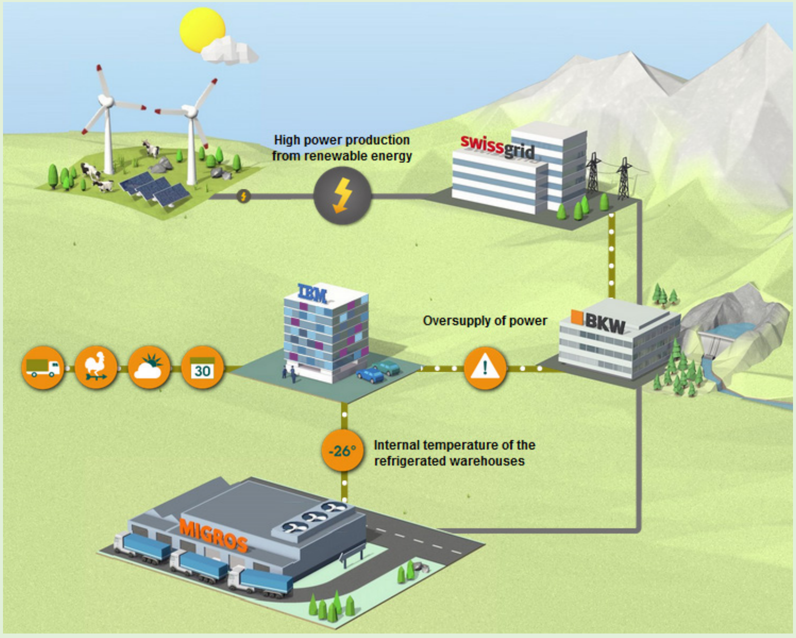
Demand response can furthermore be seen as a cooperative activity involving utilities, their customers and, increasingly, third-party energy-service providers of more sustainable and efficient power systems[5]. This is feasible as a result of numerous transformations in the electricity value chain (see Figure 4), effectively turning the traditional grid (characterized by large generation stations, centralized control, one-way power flow and

[4] See Pallensky and Dietrich (2011) for an overview and taxonomy for demand-side management, including energy efficiency and DR.
[5] As per the European Commission JRC "Smart Grid Project, Outlook 2014" available at http://ses.jrc.ec.europa.eu/smart-grids-observatory

regional power adequacy optimisation) into a smart grid (characterized by distributed generation and renewable energy sources, flexible operation and maintenance and two-way communication that facilitates DSM).
The ongoing developments in the power systems affect all stakeholders, be they customers, retailers, DSOs, TSO/ISO, regulators and new entrants (e.g. aggregators).

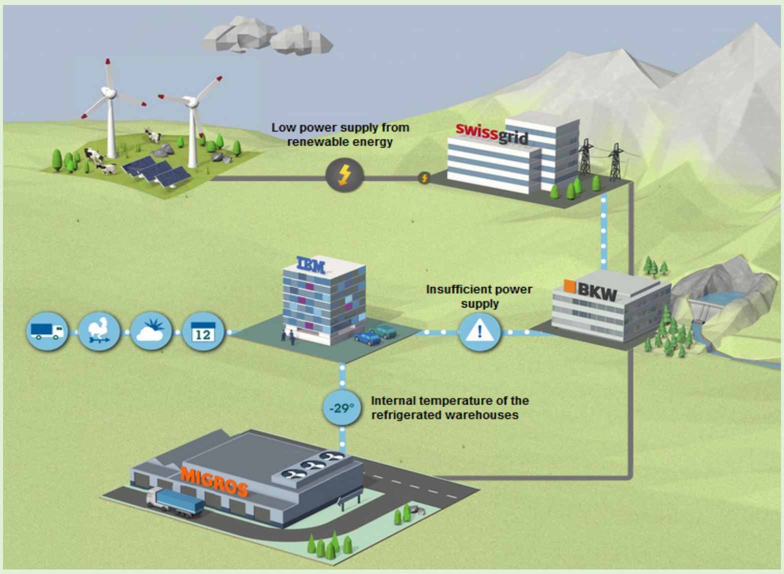
Box 1 | DR illustration: "FlexLast" Pilot Project (Switzerland)

The FlexLast Project was a smart-grid, collaborative demonstration project between Swissgrid, BKW, IBM and Migros to study the potential of DR, wherein refrigerated warehouses store energy for demand-side load management, to facilitate the integration of variable renewable generation. The figures below show two renewable energy supply scenarios, one with an oversupply of renewable energy (top figure) and another one with an insufficient supply of renewable energy (bottom figure).



Scenario 1: Oversupply of renewable energy. To absorb the oversupply of energy, Swissgrid alerts BKW to use more power. IBM is informed of the oversupply, on the basis of which it performs some quantitative analysis for optimal demand-side control. Thus, taking into account the flow of goods to Migros' warehouses, IBM recommends that the warehouses consume more energy by setting a lower target temperature, at -29°C, requiring ramping up of cooling systems. As a result, the warehouses are able to absorb a higher proportion of renewable energy supply than under normal operating conditions, effectively storing energy so that energy needs not be consumed in subsequent periods, without damaging the goods. Scenario 1 also illustrates the case where DR can reduce variable renewable energy curtailment.

Scenario 2: Insufficient supply of renewable energy. Swissgrid alerts BKW that demand power regulation is needed. Information about energy flow is sent to IBM. Based on this information and assuming that internal temperature of warehouses is -29°C, i.e. below the minimum threshold required for preserving the goods, IBM recommends Migros to ramp down its cooling systems for a target temperature of -26°C. As a result, less energy is consumed. The feasibility of this scenario is highly dependent on the initial internal temperature of the warehouse as well as the cooling requirements, which depend on the flow of goods to the warehouse.



These two scenarios highlight the collaborative nature of DR and its potential as well as the multiplicity of factors that need to be satisfied for its successful operationalisation on an intra-day basis
Source: Adapted from http://www.zurich.ibm.com/flexlast/infographic_en/

1.2. Benefits of demand response

The potential benefits of this paradigm shift from 'generation following demand' to 'demand following generation' fall in three broad categories: **system reliability**, **economic efficiency** and **environmental benefits**. These benefits have been widely documented (Braithwait, 2003; DOE, 2006; IEA, 2003; Hogan, 2009; OFGEM, 2010) and are briefly described below, as seen by proponents of DR.

System reliability

- DR is becoming an important balancing resource with increasing shares of variable and uncertain renewable energy generation sources like wind and solar. DR can enable capacity firming of intermittent generation, and thus contribute to system reliability.
- DR can be used for regulation and ramp constraints mitigation, especially in the presence of renewables.
- DR can help in the balancing of schedule deviations, e.g. thermostatically controlled load can be mobilised to provide virtual storage through intelligent load shifting, and thereby contribute to system reliability.
- DR, combined with storage units, can contribute towards the provision of frequency control reserves.
- DR can be used to respond to contingency events, e.g. in the form of contingency reserves, or through other electric load management that takes place outside formal organised wholesale markets.

Economic efficiency

- By providing balancing capacity, DR reduces the need for peaking plants and helps overcome the missing-money[6] or scarcity pricing problem (Shanker, 2003), or defer the construction of peaking generation units (DOE, 2006).
- In the long run, a dependable demand reduction through DR can enable deferral of capital expenditures, both in generation capacity and in transmission and distribution upgrades. This requires widespread roll-out of smart technologies and increasing market intelligence.
- DR entails a potential to lower the wholesale prices of electricity by lowering usage in peak hours (see e.g. Hirst, 2002) and enabling least-cost economic dispatch, whereby generating units with lowest incremental costs are used first.
- Exposing end-users to dynamic real-time prices can provide the incentive to consume electricity in an economically efficient manner (Schweppe et al., 1988).
- DR can enable utilities and other parties to provide consumers with better service, including potentially lower electricity bills.
- Market-based virtual power plant (VPP) operations also ensure DR resources compete on the market.
- Because DR requires demand-side and supply-side resources to compete on a level-playing field, DR increases competition and innovation in the electricity market.
- DR can reduce unscheduled load shedding and associated penalties.
- DR can contribute to increasing energy autonomy of regions through an increased capacity to use local renewable energy resources.

Environmental benefits

- Some DR programmes can lead to energy conservation. For example, a significant portion of peak loads may not be just shifted but shaved. There could also be vicarious benefits, whereby DR could lead to behavioural changes that foster energy savings. Environmental externalities associated with generating electricity (from non-renewable resources) for consumption are thus reduced.
- Primary environmental benefits derive from the fact that DR is a low-carbon power system 'resource' in so far as (i) DR leads to load curtailment (as above), or (ii) DR leads to load shifting to times where renewable generation is high, or (iii) DR leads to load shifting to off-peak period and off-peak generation is low-carbon emitting.

[6] A missing-money problem arises when energy or electricity price is too low to justify additional investment to meet energy demand beyond a certain level and is often associated with the absence of scarcity pricing due to price caps.

- Peak-load capacity is often fossil-fuel-based and therefore has adverse impacts on the environment, e.g. through greenhouse gas emissions. DR can reduce such environmental externalities when it substitutes for peak-load generation.

As a case in point, in a European collaborative study, VaasaETT, Capegemini and Enerdata (2008) attempted to evaluate the benefits of two different demand response scenarios:

(i) A moderate scenario, which maps the outcome of DR assuming persistence of current market trends;
(ii) A dynamic scenario, which is based on the most optimistic outlook for demand response and is based on full support from EU Member States and all relevant stakeholders.

The results are shown in Table 1, indicating that under the dynamic scenario, 25% of EU 2020 Targets for CO_2 emissions reductions and 50% of energy savings target could be reached.

	Moderate scenarios	Dynamic Scenario	Dynamic Scenario % of EU 2020 Targets
Energy savings	59 TWh	202 TWh	50%
CO_2 emissions reductions	30 Mt	100 Mt	25%
Peak generation capacity avoided	28 GW	72 GW	
Avoided investment	€ 20 billion	€ 50 billion	

Table 1: DR Potential in Europe and associated benefits.
Source: VaasaETT, Capgemini and Enerdata (2008)

1.3. Emerging power system risks involved in the development of demand response

Planning risks

The transition to a low-carbon economy, encompassing the policy-driven decommissioning of baseload power plants (coal/nuclear) and the mothballing of fossil-fuel-based peak-load generators, creates much uncertainty regarding the availability of sufficient capacity to meet peak demand.

DR has traditionally been used to reduce peak demand and is still considered as a way to reduce the missing-money problem. It may however be possible that, in the context of large-scale integration of renewable energy sources, DR may exacerbate this problem by moving value from energy to capacity markets.

Since DR will also have long-term effects on the energy portfolio, encompassing distributed generation and storage, it is important to adopt an integrated approach to long-term capacity planning, at both the level of generation and transmission and distribution.

Operational risks

Imbalance risks

Due to their variability and unpredictability, high penetration of intermittent renewable energy resources (IRES) will make it more challenging to balance demand and supply in real time. DR, in particular, DR for ancillary services can reduce the imbalance risks. However, notwithstanding the dearth of field tests, DR for ancillary services face a number of market and regulatory barriers. These have to be brought down to reduce the imbalance risks associated with decarbonisation of the system.

Curtailment risks

IRES usually have to be curtailed when generation exceeds transmission and distribution capacity, e.g. due to physical constraints on the loads. In systems where the baseload generators are inflexible, IRES may have to be curtailed to keep generation costs low (Henriot, 2015). However, this curtailment will not benefit all stakeholders. Further work is needed to assess the costs and benefits of IRES curtailment.

Market risks: price and volume risks

Although DR can decrease wholesale prices in the long run, opening retail markets to dynamic pricing may expose consumers to price volatility. And, depending on the contracts, some customers may face volume risks in the form of unscheduled curtailment. These risks have to be mitigated to foster DR participation and ensure that consumers benefit from energy transitions.

1.4. Risk governance challenges

Assuming that demand response is needed to achieve successfull energy transitions in Europe, failure to deploy it or poor implementation would result in new risks for various actors, including utilities and consumers. Risk governance of demand response should thus appropriately address the barriers to achieving the full potential of demand response, taking into account the broader context of energy transitions.

Risks of not or poorly deploying demand response

- Failure to meet policy goals, such as renewable energy deployment targets or CO_2 emission reductions targets
- Increase in grid infrastructure costs and associated investment, due to additional need for standing generation reserves, storage capacities and grid interconnection
- Economic and social welfare losses through the inability to fully exploit the increasing potential of renewable energy sources to offer grid parity and (even) below grid parity price
- Price volatility risks in both wholesale and retail electricity markets.

Barriers to achieving full demand response potential

- Empirical evidence of achievement since the 2005 Energy Policy Act (EPACT) in the US indicates a past tendency to overestimate potential demand curtailments and load control from demand response (Cappers et al., 2009). Thus **quantification of expected gains** is needed (SEDC, 2014), and is challenging because it requires establishing a customer's baseline[7] usage though an Evaluation, Measurement and Verification (EM&V) protocol, which is used to establish energy reductions.

- In order that demand response can be a viable alternative to supply-side grid investment, it is important to understand the difficulties to meet curtailment commitments or targets. These include:
  - **Poor consumer segmentation**. Consumers differ according to their load profile as well as to their preferences. A failure to tailor incentives to the consumer type can decrease the cost-effectiveness of DR programmes.
  - **Lack of consumer engagement**. Involving consumers with different attitudes, acceptance and motivations is critical to the success of DR. Thorough understanding of these drivers is needed to inform DR deployment and management.
  - **Lack of investment in enabling technologies**. Smart meters allow utilities or load aggregators to provide dynamic pricing, and interval meters enable the development of more accurate consumer baselines that are critical to estimating peak demand reductions and its proper compensation. In the absence of (timely) investment in these technologies, the potential for managing demand loads is significantly reduced.
  - **Smart meter privacy and security scare**. Smart-meter privacy risk remains a key barrier if private data are collected by external parties for other usage than DR. There are also concerns that smart meters can be a target for malicious cyber-attacks (Anderson and Fuloria, 2014).
  - **Lack of intermediaries as curtailment service providers and/or their diversity**. This may be due to market power issues, and market rules and regulations for the provision of different DR services.
  - **Regulation** may oppose DR altogether, discourage DR (e.g. rate of return regulation favours capital investment) or may be lacking, as in the case of interoperability standards.

[7] The baseline is the level of electricity that would have been consumed during a DR event in the absence of curtailment efforts.

Broader issues in the context of energy transitions

- In Europe, completion of the internal energy market also requires the implementation of the Energy Efficiency Directive 2012[8], which includes provisions for demand response[9] and related price signals, distributed generation and energy efficiency.
- Decentralised operation in line with the EED in the context of the internal electricity market (IEM) requires a **harmonized regulatory regime**. In Europe, demand response activity has increased between 2013 and 2014 but there are still significant regulatory barriers in the majority of countries. Although Network Codes have been designed to govern cross-border electricity flows and DR is considered a key component of EU's IEM (EC, 2012) , there are no regulatory provisions for national DR deployment (CEER, 2014).
- The design of sustainable electricity markets will require **learning and adaptation** for moving from demonstration to deployment. Transitions need to be sequential, allowing for learning-based adaptation of strategies on the basis of well-defined key performance indicators (SEDC, 2013).
- Unlike energy efficiency (EE), where EE targets have been set at a European and Member State level, there are real policy issues regarding the appropriateness of setting DR targets.
- As prices act as balancing mechanisms, they may be subject to heightened fluctuations. Commodification of electricity through liberalisation, including the IEM, and DR-related dynamic pricing increase the need for **intermediaries to hedge price fluctuations or for innovative pricing schemes** in order to mitigate customer price risk (Borenstein et al., 2002).
- Cross-border balancing power exchanges may become an important part of a nation's DR portfolio, but this would require appropriate locational pricing to be in place.
- Changes in overall policy frameworks may be needed to **motivate investments in relevant energy and capacity markets**.

1.5. Outline

Based on the preceding, this report is organised in five parts. Starting with the downstream supply chain, i.e. the end-user, **Chapter 2** highlights the importance of assessing the realisable potential, the mainstream methodologies, as well as the differences between the technical and economic potentials, and the capacity value of demand response.

Distinguishing between commercial and industrial (C&I) consumers and residential consumers, **Chapter 3** discusses the need to, barriers to and some practices for consumer engagement, as well as the state of DR development in Europe across the two customer segments – C&I and residential.

Chapter 4 delves into the challenges of designing appropriate business models to create and capture value from DR, especially from individual stakeholder's perspective. The importance of enabling market designs and regulatory frameworks are addressed in **Chapters 5** and **6**, respectively, and **Chapter 7** lists a few open questions.

[8] http://ec.europa.eu/energy/en/topics/energy-efficiency/energy-efficiency-directive

[9] The 2012 Energy Efficiency Directive, Article 15.8 stipulates that "Member States shall ensure that national regulatory authorities encourage demand side resources, such as Demand Response, to participate alongside supply in wholesale and retail markets".

2.
ASSESSMENT OF DEMAND RESPONSE POTENTIAL

Demand response was originally created to shave peak demand, and even today demand response potential is often measured in terms of the percentage of peak demand. For example, the DR operator Energy Pool[10] estimates the potential of demand response at approximately 10% of national peak consumption. But, more generally, demand response is increasingly valued for its potential for providing other forms of power system flexibility, e.g. spinning reserve, at higher renewables penetrations. Although DR is already being deployed, the realisable potentials of different DR resources are largely uncertain as they are hard to assess.

2.1. Importance of demand response potential assessment

Assessing demand response potential is an important exercise in order to:

- Help prioritisation of demand response types to meet policy goals

A non-negligible share of the future electricity market may be dedicated to DR and other flexibility options. Operators are advised to conduct comparative cost-benefit analyses of different flexibility options for different time scales. For instance, back-up generator-based DR can provide an easy and quick solution that meets the majority of the current market design conditions and provides significant capacity. However, this approach does not contribute to reduce CO_2 emissions if these generators use fossil fuels. -Also, it is not clear whether backup generation should appropriately be considered as a demand response resource, partly due to lower efficiencies and local pollutant emissions.

- Enable regulators and stakeholders to design appropriate policies to foster participation and innovation

The potential is likely to evolve over time as different electricity markets (ancillary services and capacity) open for DR and the number of market players increase as a result of lower entry barriers. Technological progress, such as home automation, and trends such as increasing interest in decentralised electricity sharing, will increase the potential, but this requires that an appropriate legal and regulatory framework is in place. Demand reduction/turndown-based DR is harder to implement due to the complexities of individual appliance control and variability in usage profiles. As a result, the realisable potential of turndown-based DR is highly uncertain. But, if almost all areas of society were to participate, it could help greatly to meet climate change targets at least in the short term. In the long term, DR only makes sense if it can compete with other flexibility options.

- Help system planners evaluate power system risks and the assessment of supply-side investment needs

The lead time for supply-side investment is long, making it important to assess to what extent DR can be considered a viable alternative to such investments and for what time frame. Besides, DR may entail some risks, e.g. price volatility risks, while nonetheless providing system benefits such as enhanced grid reliability. The risk-benefit ratio is critical in any investment decision.

2.2. Methods for assessing demand response potential

Assessing DR potential is complicated for various reasons, among which the lack of **experience in deploying and managing demand response programmes, at least in Europe**. As a result, DR potential is biased by the assumptions used in the assessment. One must also acknowledge that lack of knowledge about factors of influence and sources of uncertainty may cause assessments to deviate widely.

[10] http://www.energy-pool.eu/

Technical potential of demand response

There is a wide variety of approaches for estimating the technical potential of DR. A few examples are listed below.

- Some rough estimates of technical potential can be obtained on the basis of the availability of different demand response resources and enabling technology, i.e. using a *bottom-up engineering approach*.

- Another approach is to extrapolate DR potential from pilot studies and demonstration projects, i.e. *benchmarking*. Several pilot projects have been implemented in Europe to test different DR programmes, but their results do not yet provide a clear indication about their actual potential and value. This lack of clarity is partially due to the difficulty in measuring and comparing project results; pilot experiments conducted so far are very different in scope, scale, duration, types of incentives used, etc. Accordingly, some stakeholders propose that more and larger-scale pilot projects are needed to assess the actual potential and value of DR (EC JRC, personal communication).

- Better estimates of technical potential can be based on time series data taking into account the physical properties of systems, including the seasonal and diurnal characteristics of different energy sources and the availability of different DR resources - frequency (number of events per year), response speed and duration, ramp rates. In the case of price-responsive DR, this would involve estimating *price elasticities* of exposed customers to DR programmes.

- One standard approach, shown in Figure 5, is to calculate the DR potential as a product of the average peak energy usage, the percentage of achievable reduction by DR programme and the participation rate in each programme.

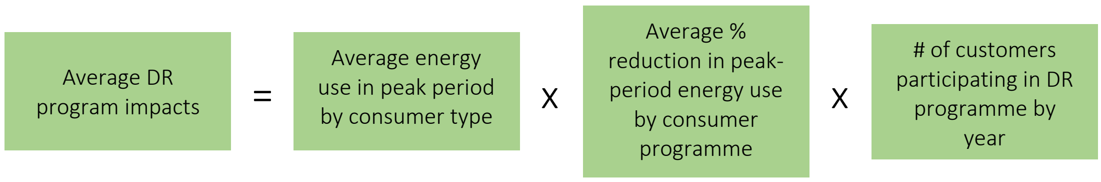


Figure 5: Key building blocks and inputs for demand response potential model. Source: FERC (2009)

The assessment requires detailed knowledge about energy usage for different end-use categories (within and across sectors) and types and subtypes of DR programmes (e.g. incentive-based or price-based programmes, DR for ancillary services or direct load control).

For example, for **residential consumers**, THINK (2011) proposes a simple approach that requires the assessment of flexibility in the load mix (storable, shiftable and curtailable) taking into account the heterogeneity of consumers and end-users. For example, the same appliance may enter a different category depending on end-use and lifestyle. The flexibility increases when moving from non-curtailable baseload to storable loads. Such an analysis of the potential can be used to select the contracts (e.g. TOU, dynamic pricing, fixed/dynamic capping contract, direct load control) that can be offered to different types of consumers, according to their preferences and needs. More research is needed in this area.

It is noteworthy that **incentive-based DR potential estimates**, such as for direct load control or curtailable load programmes, tend to be easier to obtain and require fewer assumptions than **price-based demand response**. The latter can elicit different levels of DR depending on the price elasticities of different consumer categories during peak hours as well as cross-elasticities (between two time windows of energy consumption). Price-based DR potential estimates require information about the elasticities of different consumer segments, estimation of programme penetration rates (which depends on the type of programmes and, where appropriate, the nature of default options for DR programme enrolment), quantification of response rates (number and frequency of events, price response using an appropriate measure, e.g. price elasticity of demand, substitution elasticity), pricing structure, type of signal and its information content. Since the assumptions used in these models are often fraught with uncertainty, DR potential studies should examine a range of scenarios (Goldman et al., 2007).

Economic potential of demand response

The economic valuation of DR potential requires more knowledge about the power system. It is valued taking into account various savings potentials from DR services, costs for providing the services and potential revenues from such services.

Depending on the perspective, it may also include savings associated with the avoidance of generation from expensive marginal generators. For instance, for residential consumers, such cost savings will be reflected in lower prices and should be counted as an indirect economic gain. Furthermore, the economic DR potential will be affected by any payback (or rebound) effect associated with a DR event.

The capacity value of demand response

The capacity value of DR refers to the share of technical potential that is available to provide flexibility when called for. The capacity value is likely to vary over different time scales, depending on the purpose of the assessment. The gap between realisable potential and capacity value is highly uncertain and has significant implications for investment decisions in capacity reserves.

2.3. Demand response measurement and verification

- Baseline measurement and DR performance

Baseline estimates are required to measure the extent of curtailment and to verify compliance with contract requirements. Most common methods use regression of hourly demand against temperature and hour of the day for individual sites during non-event days. More sophisticated approaches reflect variability and sensitivity of loads. Given the diversity of approaches, some standards for baseline evaluation and for measurement and verification are needed. KEMA (2013a) has proposed the following performance evaluation methodologies.

Performance evaluation methodologies	Valid for service type			
	Energy	Capacity	Reserves	Regulation
Baseline Type I – Interval Metering Based on demand resource's historical interval meter data, which may include variables such as weather and calendar data	×	×	×	
Baseline Type II – Non-interval Metering Based on statistical sampling to estimate electricity usage of an aggregated demand resource	×	×	×	
Maximum baseload Based on a demand resource's ability to maintain its electricity usage at or below a specified level during a demand response event	×	×	×	
Meter Before/Meter After Electricity demand over a prescribed prior of time prior to deployment is compared to similar readings during the sustained response period	×	×	×	×
Metering Generator Output Demand reduction value is based on the output of generator located behind the demand resource's revenue meter	×	×	×	×

Table 2: Performance evaluation methodologies

These different methods should be selected depending, for example, on types of products offered, size of market and its maturity.

- Gaming risks

Proper baseline assessment is important because of the possibility of gaming. Gaming arises because of information asymmetry between the end-user and the DR service provider, who does not know the usual consumption of the end-user. The latter can inflate his/her baseline consumption through misreporting or by artificially increasing his consumption over a certain period of time in order to get a higher remuneration for curtailment. Automatic DR could reduce the possibility of gaming, which is a risk under Baseline Type I and Baseline Type II, as well as the need for detailed modelling.

Another possible solution could be that the regulatory authority allows the service provider and the end-user to write a special DR contract. One such contract would require the end-user to pay a fee that increases proportionally with the declared baseline consumption. This should deter baseline inflation. Other parameters of the contract can then be adjusted to counterbalance the higher baseline fee in such a way that curtailment remains as attractive as possible.

3. CONSUMER ENGAGEMENT IN DEMAND RESPONSE

Two recent reports from Navigant Research (2014a, 2014b) estimate that the expected revenue from residential demand response and from commercial and industrial (C&I) markets could, by 2023, respectively reach US$2.3 billion and US$38 billion (for an expected DR capacity of about 132 GW) worldwide. These estimates assume widespread acceptance and implementation of two-way communication thermostats and of automated demand response. Yet, it is difficult to measure customer willingness to engage, and this section suggests that more behavioural research is needed about the non-financial and non-technical barriers and motivations to DR, and the type of incentives that could encourage consumer participation in demand response.

3.1. Barriers to demand response and suggested solutions

Commercial and industrial DR

Lack of DR modelling, forecasting tools and reliable control strategies have traditionally stalled the development of convincing business cases for C&I DR, but the past years have seen many advances in this area. Today, large technology suppliers such as Siemens and ABB provide Demand Response Management Solutions (DRMSs)[11,12].

But consultation with C&I customers uncovered that other technological developments may compete with DR, for example when cheap storage is perceived as an alternative to demand response rather than a complementary technology. Yet cheap local storage is a technology of the future. The preference to 'wait and see' how energy storage develops is because DR may require costly investment and deep system adaptation while storage does not.

This said, a number of C&I consumers see benefits in adopting DR as a means to cut cost in the short run. As the market for DRMS is becoming increasingly competitive, further expansion of C&I demand response market is expected as value propositions from the service providers become more compelling. These may include solutions to use new DR and existing flexibility resources in parallel.

A potential barrier to C&I DR is the flexibility of the processes. In the commercial sector, where thermal loads such as refrigeration, heating and cooling are used to provide DR, the capacity value of DR is limited by the hysteretic property of the loads. This is because these loads operate in an 'on' or 'off' fashion. It is very difficult to force a system to an 'off' mode if it is 'on' without disrupting the end-use services of the load.

When it comes to industrial processes, DR has been traditionally provided by back-up generators. But such back-up generators are generally neither energy efficient nor carbon efficient. DR then requires the flexibilisation of industrial processes in such a way that industries' outputs are not negatively affected. Such flexibilisation varies across processes and across industrial sectors.

Residential DR

The biggest challenge for DR lies in the residential sector, due to:

- Lack of consumer knowledge and engagement
  - Consumers often do not have sufficient knowledge about the electricity they consume (or how the bills are calculated) and/or are not aware of DR programmes. Information and education about the benefits

[11] http://w3.siemens.com/smartgrid/global/en/products-systems-solutions/smart-metering/emeter/pages/demand-response.aspx
[12] http://new.abb.com/docs/librariesprovider139/default-document-library/drms-overview_abb.pdf?sfvrsn=2

of DR and how to derive these benefits will be important success factors. Madlener (2014) shows that appropriate feedback on consumption via electricity bills can trigger energy savings.

- Consumer engagement strategies need to be developed so that consumers successfully assume their new role as active participants in the electricity system. Community dynamics could also be further investigated.

Limited user acceptance, privacy concerns and fear of losing control

Where awareness is not an issue, there is much scepticism about DR because of privacy concerns and the perceived complexity of DR programmes. News headlines such as "Big Brother to Control Your Fridge: Power Giants to Make Millions - But You Must Pay for 'Sinister' Technology"[13] also do not reassure consumers. If the homeowner (not the utility) is still in control, there is much less risk for privacy invasion. But in general, lack of acceptance of DR, because it entails moving away from currently predominant perceptions of security of supply (at least in industrialised countries) is a major risk for its wider diffusion.

Lack of real value for households

The monetary benefits for consumers are often not significant enough to motivate them to sustain their engagement. Moreover, the cost of equipment needed and efforts to install these are quite significant, at least in the residential sector. Residential consumers can only be expected to participate in DR programmes if the benefits outweigh the investment costs and consumers' efforts and, even then, it is not clear whether residential DR (RDR) will be cost-effective. For example, using French data, Léautier (2014) estimates that switching from flat rate pricing to Real-Time Pricing (RTP) increases net surplus (consumer and producer surplus) by €5-10 per year. Even if the surplus was higher, say €20-40 per year, it may still not cover the cost of enabling technologies, e.g. smart meters, or the commercial cost of engaging customers.[14]

3.2. Good practices to foster participation

Consumer engagement pyramid

Opower (2014) suggests an incremental approach to acquiring new customers and for managing their long-term engagement. As shown in Figure 6, consumer engagement and empowerment is done in three stages, starting with behavioural demand response. This first stage is followed by consumer engagement in dynamic pricing programmes and, eventually, their enrolment in advanced DR programmes, where consumers are empowered to shift and reduce their electricity consumption without loss of convenience.

[13] http://www.dailymail.co.uk/news/article-2315863/Big-brother-switch-fridge-Power-giants-make-millions--pay-sinister-technology.html
[14] For this reason, it is often argues that C&I demand response should be prioritised, as it is the case United Kingdom.

Behavioural demand response (BDR) has the advantage that it does not rely exclusively on monetary benefits. BDR provides consumers with indirect feedbacks such as education, information and campaigns that are important, but have a very small impact on DR participation. BDR also provide direct feedbacks such as in-home displays, smart meter data monitoring, performance feedbacks (including neighbour comparisons) that have a larger impact on DR participation. Any success of BDR depends to a large extent on the adaptation of feedbacks to the social and cultural context of consumers.

In terms of signals, dynamic pricing signals have the highest leverage. Dynamic pricing has been shown to increase DR participation in numerous studies (e.g., Faruqui and Sergici, 2010). To date, however, only a limited

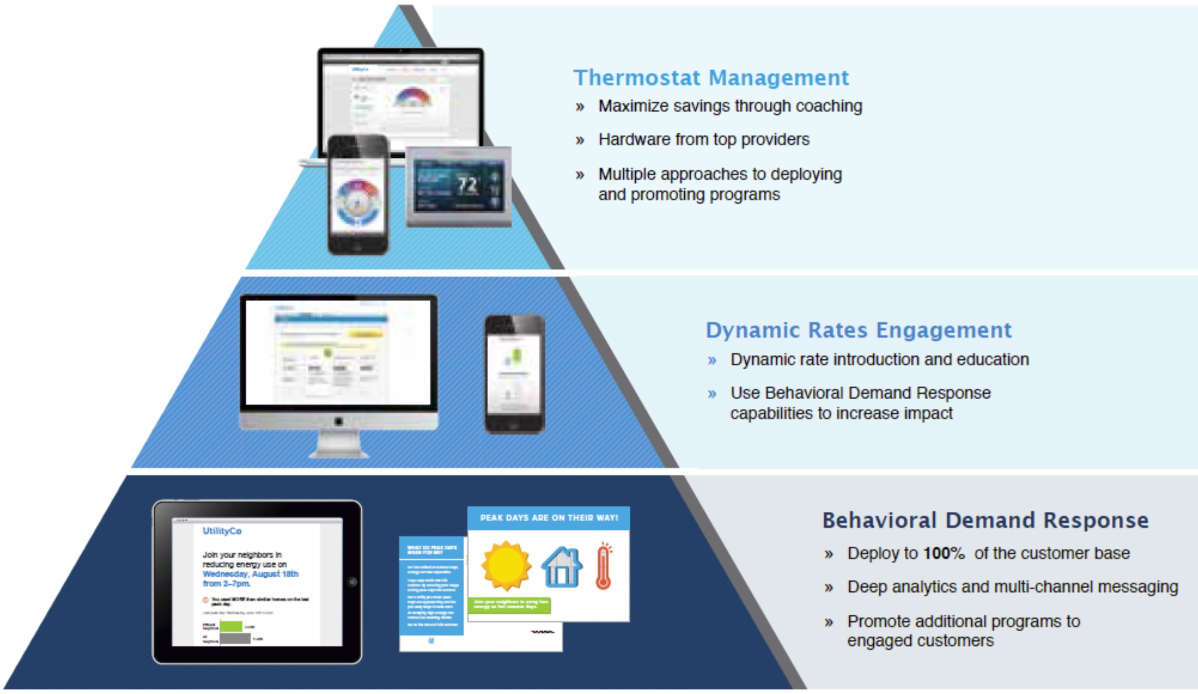


Figure 6: Opower consumer engagement pyramid. Source: Opower (2014)

number of consumers are on time-based rates (although a number of countries do have high/low tariff schemes), often times because small consumers do not have direct access to electricity markets, nor do they know the share of their electricity bill that pays for energy versus distribution and other charges.

Consumer segmentation

Consumers have different preferences. Thus, DR products and services must be aligned with consumer value perception. In an exploratory study, Kaufmann et al. (2013) showed how individuals with heterogeneous value perceptions could be organised in four clusters: 'risk-averse', 'technology minded', 'price sensitive' and 'safety oriented'. Table 2 below shows the resulting range of product and service offerings that result from such segmentation.

Attribute	Cluster 1 **Risk-averse**	Cluster 2 **Technology -minded**	Cluster 3 **Price sensitive**	Cluster 4 **Safety oriented**
Tariff (low/high) cents per kWh	11/17	11/17 or 6/50	6/50	11/17
Base fee per month (CHF)	23.00	23.00	23.00 or 23.00 + 2.00	23.00 + 2.00
Remote meter reading with accurate monthly reading	✓	✓	✓	✓
Real-time consumption feedback via				
- in-home display	✓	×	✓	✓
- online web portal	×	×	×	×
- mobile device	×	✓	×	×
Programming and steering services	×	✓	✓	×
Home security and surveillance services with alert functions	×	✓	✓	✓

Table 3: Service bundles for different segments. Source: Kaufmann et al. (2013)

Tariff structures, pricing vs. rebates

Four categories of tariff structures are usually discussed in the literature, namely Real-Time Pricing (RTP), Time-of-Use (TOU), Critical-Peak Pricing (CPP) and Peak-Time Rebates (PTR). These are briefly described below:

- RTP is a price that is set on an hourly basis; it reflects what happens in spot markets and must be communicated to consumers.
- In TOU pricing, a few time periods are defined and a different price per KWh is fixed for each time period. The simplest example are prices that vary by time of the day, e.g. morning, mid-day and night.
- CPP is a constant price that is fixed, usually at the signature of the contract; its use is usually limited to a number of days per year.
- PTRs are paid to customers if they decrease their consumption relative to a counterfactual baseline, as if consumers resell electricity. It is also called 'active demand response'.

In general, dynamic pricing is preferred to flat rates because the latter have an implicit cross-subsidy from low-demand consumers to more peaky consumers. In the context of DR, experimental studies have shown that pricing events can lead to 0 – 7 percent reduction in energy usage, but when pricing events are coupled with In-Home Displays (IHDs) of energy consumption, reductions in energy usage range between 8 and 22 percent (Jessoe and Rapson, 2014). Based on a survey of 15 experiments, Faruqui and Sergici (2010) and Faruqui, Sergici and Sharif (2010) confirm that customers respond to price signals and that CPP produces larger effects than TOU pricing. They also found that IHDs influence consumer behaviour, and that there is strong complementarity between pricing and technology, in particular between CPP and Direct Load Control (DLC) and between IHD and prepayment systems.

Although the merits of dynamic pricing are largely advocated, households generally have low price elasticity and the success of dynamic pricing will depend on price elasticities of different consumer segments as well as consumer acceptance of associated wealth transfers. In a simulation study, Borenstein (2007a) shows that wealth transfers result from a switch from flat rates to both TOU pricing and RTP but that the effect on consumers' electricity bills is only significant for those consumers who have quite high elasticity. The magnitude of wealth transfers are unclear, and may be biased by the assumptions used for the simulations. Nonetheless, adverse wealth transfers caused by real-time pricing can be mitigated by well-structured two-part tariff programmes, consisting of a baseload purchased at a regulated price and an RTP component. Two-part tariff programmes are also preferable to more complex tariff structures, since consumers typically dislike complexity.

One disadvantage of RTP is that it may result in bill volatility and may require hedging instruments to build consumer acceptance (Borenstein, 2007b). Regulation could also deliver a positive balance between costs and benefits through such mechanisms as the bill-shock regulation and default options as described below.

- Bill-shock regulation (Grubb, 2015) requires firms to “disclose information that substitutes for attention” on the grounds that information and attention (to past usage, size of bills) are substitutes. It is based on the notion that consumers have different degrees of sophistication. Sophisticated consumers track past usage and make sure that their bills do not cross a certain threshold. Naïve consumers on the other hand can become inattentive and also fail to anticipate their own inattention. As a result, they may sign up a contract designed for sophisticated consumers and end up with runaway bills because of their inattention. Bill-shock regulation makes a provision whereby these naïve consumers are alerted when they cross some pre-determined thresholds as stipulated in the contract. Grubb (2015) argues that bill-shock regulation can increase social welfare and can benefit consumers by reducing cross–subsidisation of the inattentive consumers by attentive consumers. **Its application to DR contracts has yet to be explored.**

- Default options such as Sunstein and Reisch’s (2014) green default tariff suggests that the regulator sets a green electricity contract as the default contract. Active consumers may decide to switch to grey electricity because it is cheaper, while passive consumers are automatically ‘green’. In the context of DR, the impact of default options for consumer recruitment, as in Opt-in default, is being explored (e.g. Cappers et al., 2015). Clear results are yet to be obtained. An alternative to default options could be to use nudging to influence consumer behaviour (Thaler and Sunstein, 2009), but it has not been demonstrated that nudging people into a certain behaviour can work in the long term.

The empirical and experimental works discussed above indicate, at least in the US, that residential consumers would respond to fluctuations in electricity price. These responses are triggered by the monetary incentive of a reduced electricity bill. But, when exposed to dynamic pricing, consumers may be motivated to reduce their consumption for other reasons as well. For instance, dynamic pricing sends signals to consumers about the state of the grid and trigger load curtailment or load shifts, provided consumers are aware of the system risks and long-run benefits of these DR events. Consumers’ sensitivity to prices (i.e. price elasticity) may also increase over time with the deployment of local generation as consumers become accustomed to avail of energy services for ‘free’ thanks to, say, roof-top photovoltaic systems (McKenna and Thomson, 2014).

Astier and Léautier (2015) further suggest that CPP and RTP, i.e. passive DR, is a more viable policy option than active DR, i.e. PTR, in which customers resell power they have purchased to the market. This is because, it is important to estimate the baseline in order to implement PTR. As mentioned in Section 2, this is challenging because of the asymmetry between the DR operator and the customers, who have strong incentives to inflate their baseline. Improving baseline estimation could reduce the negative effect of information asymmetry. At the same time, the right incentives mechanisms need to be set up. This is however a very difficult task.

Information and control technologies

Consumers must dispose of the appropriate smart appliances/system in order to:

- Receive e-bills and e-information
- Receive dynamic price signals and curtailment requests for time-based DR
- Automate load flexibility.

To this end, the installation of smart meters is necessary. However, advanced smart meters are not yet cost-effective (see, e.g., EurActiv, 2012; E&Y, 2013, Léauthier, 2014) and varies with the context (IEE, 2011). Installations of smart appliances for ‘smart homes’ may also be hindered considering the existing stock of appliances. Moreover, although desirable, the costs of installations to automate the load flexibility are too high and associated aggregation techniques and communication are still too complex.

Although the above may hold true at a cursory level, going forward, a necessary first step could be to do a thorough segmentation and categorisation of what can be automated in each household. Consumer acceptance of automation will depend on reasonable defaults for different loads and the possibility to override. Contracts can ensure that consumers are protected against non-contracted remote disconnection without prior approval.

Last but not least, if dynamic pricing and automated DR are to take off in the residential sector, it is quintessential to define mechanisms for a 'fair' allocation of the cost of metering infrastructure. This would foster wide roll-out, while also enabling small loads to participate in DR and guaranteeing minimal market entry barriers.

- Competition in retail markets

Competition is needed in RDR to diversify the portfolio of offerings and maximise consumer enrolment in DR programmes (Eurelectric, 2014). In effect, consumers have heterogeneous preferences and therefore varying willingness to pay for DR product characteristics, e.g. reliability levels, time of use, environmental impact, etc. Product differentiation requires innovation, which in turn depends on the financial viability of the product, the availability of advanced metering infrastructure (AMI), and the level of consumer engagement.

Regulation can foster retail competition by providing incentives for innovation and ensure access to price signals.

3.3. Residential vs. C&I Demand Response

DR is developing with large diversity in the residential sector (Figure 7) and the industrial sector (Figure 8) both across and within countries, with the exception of France and Finland, where both RDR and industrial DR are established. The debate is ongoing as to whether to promote C&I DR or residential (also referred to as distributed) DR. The latter relies on the aggregation of a significant number of small residential loads, but engenders a high cost per consumer. In France, while there are about 15 service providers for C&I consumers, only one currently offers distributed DR and has been receiving a governmental contribution towards its cost of services. This raises the question regarding the cost society is willing to pay for residential demand response and whether there are other mechanisms, e.g. bidding process, which could lead to more cost-effective DR provision.

At the same time, the debate of RDR vs. C&I DR is often biased by the use of cost-effectiveness of DR provision as the only assessment metric. RDR, through aggregation, can provide significant value in terms of grid stabilisation and deferred investment. Since C&I DR and RDR do not compete with each other, there is a priori no reason to prioritise one over the other, if not for market, regulatory barriers or even technical barriers.

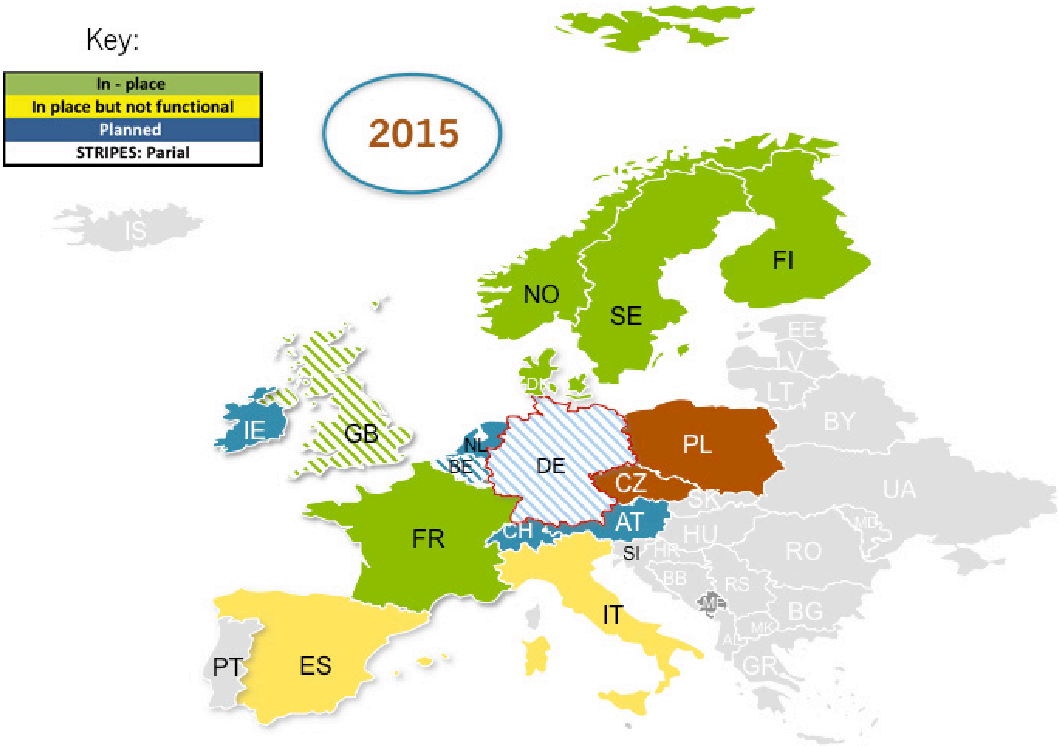


Figure 7: Residential demand response. Source: SEDC (2015)

Figure 7 shows that there are significant differences in the extent to which residential DR is deployed or planned in Europe. Where DR is in place, the mechanisms also vary widely: while in the Nordic countries (Norway, Sweden and Finland) dynamic pricing is mandated, in France the prices remain largely regulated and benefit split between the DSOs and retailers are addressed. Although residential DR is in place in Spain and Italy, it is not functional. In Spain, for instance, dynamic pricing is yet to be implemented. For Italy, the major barrier is the lack of perceived value to the consumer.

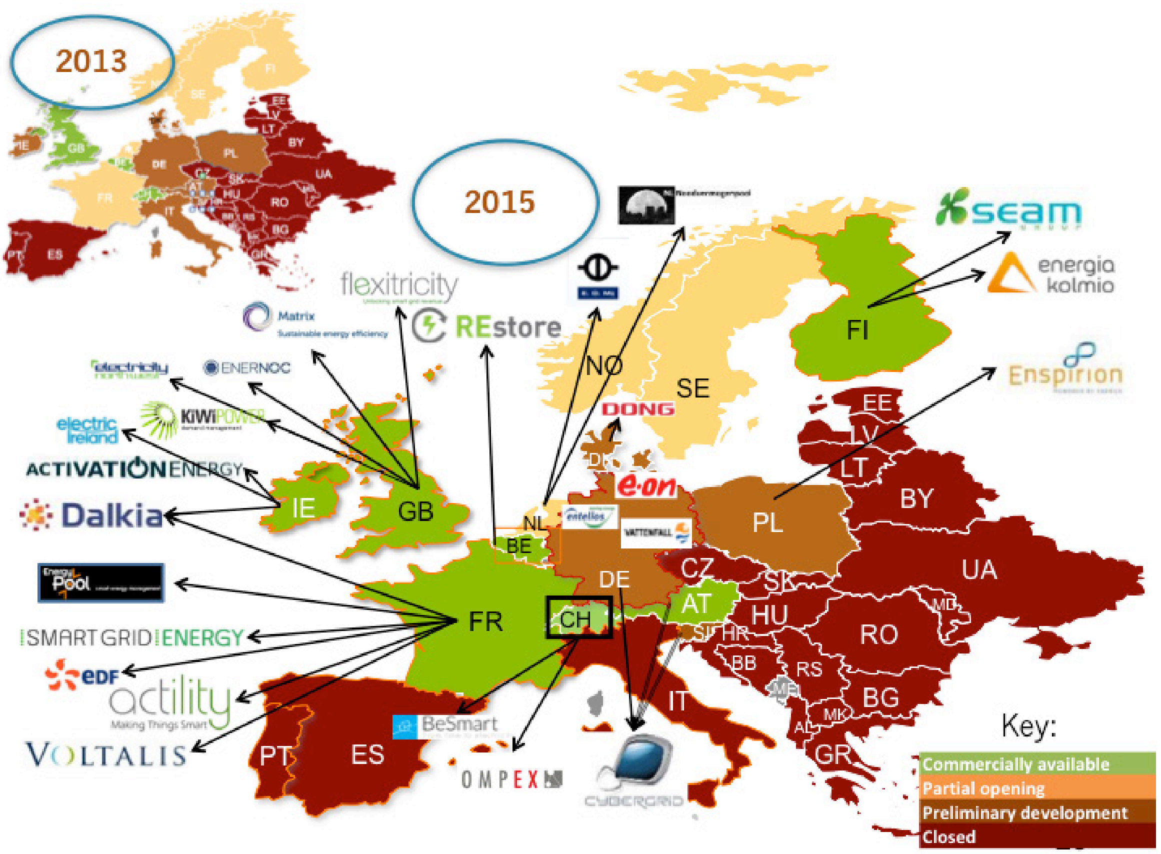


Figure 8: Industrial demand response. Source: SEDC (2015)

4.
BUSINESS MODELS TO CAPTURE DEMAND RESPONSE VALUES

The power system transformation from a 'one-way street energy-flow system' to a 'two-way communication system' creates new business opportunities, not only for new market players but also to incumbents. Future power systems will possibly also require a shift from 'volume-based' to 'efficiency-based' business models. Although definitions of business models vary (Zott and Amit, 2007; Miller, 1986; Osterwalder and Pigneur, 2010), business models rest on three main tenets namely, value proposition, value creation and value capture, which help in establishing the business case for a product or service idea, herein, demand response.

4.1. Challenges to establishing a business case for demand response

- Benefits generated from demand response have to be apportioned between many different stakeholders who provide a service along the value chain, and each share may not be large enough to engage the stakeholders in the first place.
- Relatedly, DR generates both short-term and long-term benefits that may not directly influence the profitability of the business. Besides, even if DR generates social-welfare gains, not all of it can be monetised by the relevant stakeholders, e.g. utilities and load aggregators.
- DR 2.0 and 3.0 are only now emerging, and there is a dearth of knowledge of different value drivers and sensitivity of the profitability to these value drivers.

4.2. Business modelling

The value of business modelling lies in the fact that proven business models can play an important role in increasing the deployment of DR and can help reduce some of the barriers to DR, and in particular the problem of financing the development of advanced DR. This requires an understanding of the business landscape and different business model categories.

The business landscape

The business model landscape can be illustrated as in Figure 9. The inner box shows the nine different business components that were proposed by Osterwalder and Pigneur (2010) as well as by Al-Debei and Avison (2010) in their V^4 Business Model Framework although under slightly different terminologies. The outer box includes parameters, which are external to the business, but influence the business structure and profitability of the business. EU-DEEP (2008) identified about 60 different parameters that influence business models and are grouped into six clusters, namely regulation, trade, technology, customers, generation and financial.

Categories of business models

Business models can be categorised according to their main value propositions and drivers to value creation. In the case of business models for renewable energy in the built environment, IEA-RETD (2012) focuses on three categories (i) Product-Service-Systems / Energy Contracting Models, e.g. Energy Performance Contracting; (ii) business models based on new revenue models, e.g. feed-in remuneration schemes; and (iii) business models based on new financing schemes, e.g. leasing of renewable energy equipment.

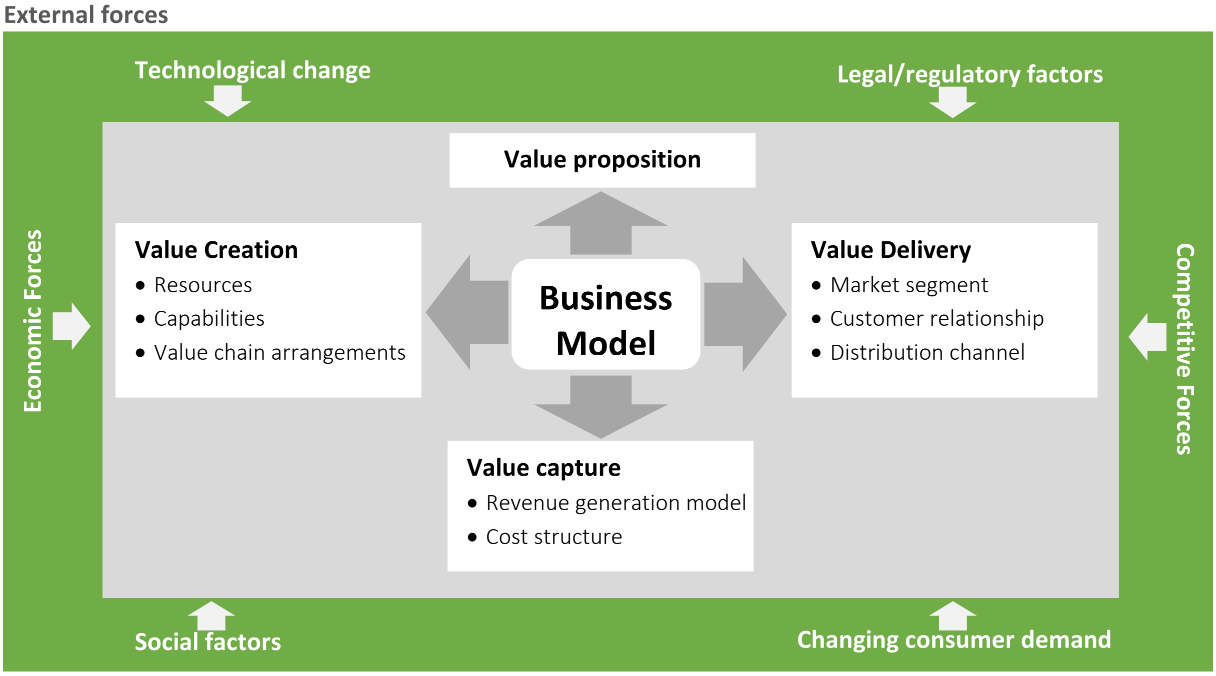


Figure 9: Business model landscape. Adapted from Kamoun (2008)

Developing and deploying business models

An important step in business models is to describe the stakeholders involved, the relationships and flows between stakeholders, and the sources of value created along the value chain. Osterwalders' business model canvas provides an intuitive way to developing the business idea. Figure 10 illustrates its application in the case of Opower.

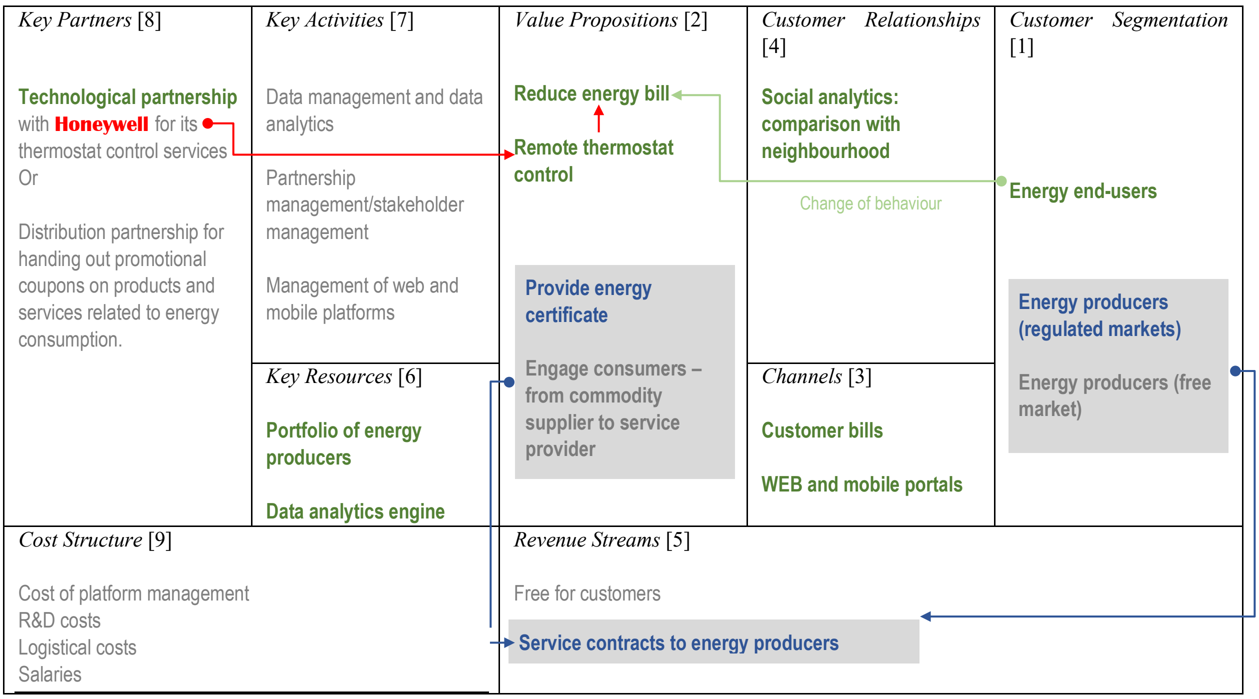


Figure 10: OPower Business Model Canvas. Adapted from: http://beagle-net.com/wp-content/uploads/2014/02/BM-BOOK.005.png

Complementary role of regulation

There is also a strong complementary role of policy makers to support business models and to ensure the best outcomes for society. For example, for utilities to shift from volume-based business models to efficiency-based business models, they need to have the right incentives. In the US, new regulation is being considered that influences utilities' revenue generation model, e.g. shareholder incentives and lost revenue recovery mechanisms, to align utilities' business interest with policy goals such as increased energy efficiency and reduced emissions (Satchwell et al., 2011).

4.3. Current and emerging business models for DR

Smart meters, distributed energy resources and electric vehicles entail new business models opportunities for distribution operators and system aggregators and, thereby, alter avenues for value capture (Giordano and Fulli, 2012). Some business models are being explored for the different market players, e.g. the TSOs, DSOs, aggregators and other energy service providers. The pros and cons of these different models have to be assessed from an integrated perspective.

Business models for aggregators

EU-DEEP[15], for example, is investigating business models for aggregators, among which:

1. A business model for aggregating commercial and industrial demand response to balance intermittent generation.
2. A business model for integrating residential-scale flexible Micro-CHP into electricity markets.
3. A business model for leveraging the flexibility of aggregated CHP units and demand response to extend the conventional Energy Service Company business.

Business models for DSOs

Changes in the power systems are allowing and requiring DSOs to adapt the way they operate networks under their responsibility. The potential future roles of DSOs have been investigated by a consortium under the project evolvDSO.[16] Further work is needed to understand which business models would fit the different roles as well as scenarios (e.g. penetration of distributed renewable energy resources, differing consumer acceptance) for which they may become established.

Business models with new market entities

RMI (2013) is also exploring new business models, e.g. platform models that involve new market players such as an independent network operator. Platform-based business models for DR are likely to be multi-sided, involving different partners. One of the main challenges of such multi-sided platform (MSPs) is that the notion of the customer is blurred, requiring a shift to notion of multiple value-exchange partners, and by corollary, the need to orchestrate multiple value propositions (Massa et al., 2015). Examples of such platform business model are a smart home platform or an E-mobility service platform (Giordano and Fulli, 2012) as illustrated in Figure 11 and Figure 12, respectively.

[15] http://www.eudeep.com/index.php?id=455; http://www.eudeep.com/index.php?id=395&no_cache=1
[16] http://www.evolvdso.eu/

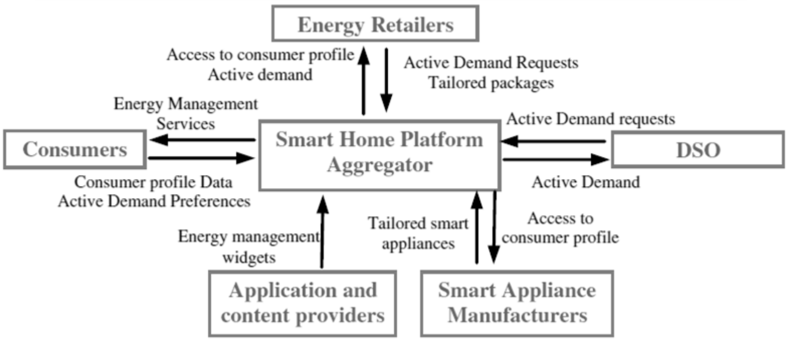


Figure 11: Smart-home platform. Source: Giordano and Fulli (2012)

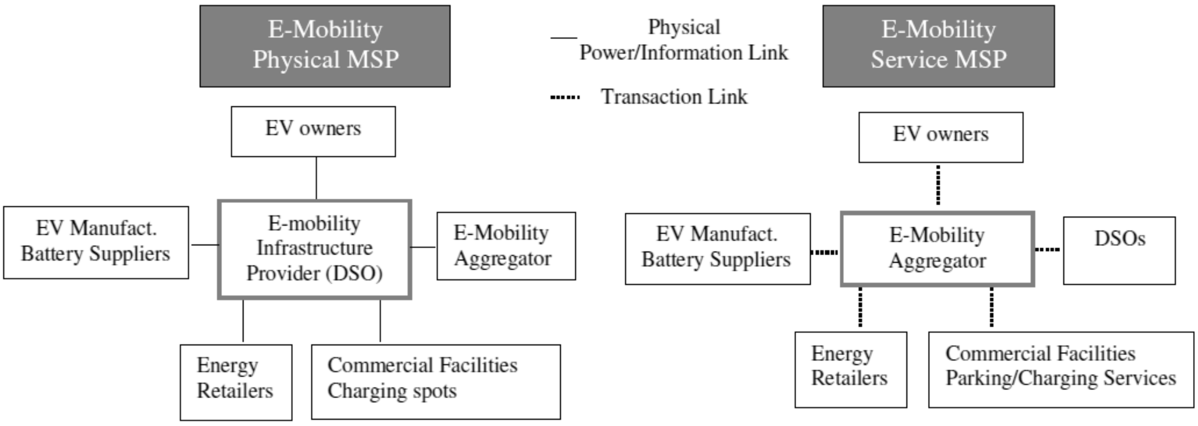


Figure 12: E-Mobility MSP (left) Physical MSP, (right) Service MSP. Source: Giordano and Fulli (2012)

5.
MARKET DESIGN TO FOSTER DEMAND RESPONSE DEPLOYMENT

Power markets are still designed from a generation perspective. In effect, only a small share of DR potential is used today in Europe and the US because (i) few markets are really open to DR, (ii) demand response is not properly compensated, (iii) there is no real level playing field between existing resources and demand-side flexibility resources, and (iv) the risk-return ratio is too high.

In the US, the FERC Order 745 that was approved in 2012 aimed at creating a level playing field. But it has been contested, causing significant uncertainties for the future of demand response. It must be noted, however, that the FERC Order 745 was based on misapplied basic economic principles[17]. A modest but interesting demand response market has been created in the PJM system[18], compensating end-use (retail) customers for reducing their electricity use (load), when requested by PJM, during periods of high power prices or when the reliability of the grid is threatened.

In Europe, the deregulation of power markets aimed at a better coordination of energy supply and demand. The focus has been on the wholesale market segment, where spot price fluctuations, due to consumption variations, provide a regulating mechanism. But, retail electricity rates are shielded from demand fluctuations due to price ceilings, flat-rate contracts and other regulatory restrictions.

Recent publications from the SEDC (2014), the EC (2015) and Eurelectric (2015) suggest that it may be necessary to revamp current market design to provide the conditions necessary for DR to become a marketable resource, and thereby have a positive and systemic impact on the efficiency of power systems. Market design features that are concerned are the market and incentive structures, market rules, and coordination mechanisms. Market re-design is complicated by the existence of different types of market segments in which DR could play a role, namely balancing services (including dynamic frequency response), peak shaving, capacity market, and energy trading (imbalance avoidance, day-ahead trading). As a result, it is difficult to determine which market segment should be prioritised, if any, depending on specific contexts. Another challenge pertains to the increasing number of players and the opening up of electricity markets to full retail competition (see Figure 13), which together imply a need for alternative coordination mechanisms.

[17] http://www.hks.harvard.edu/fs/whogan/Economists%20amicus%20brief_061312.pdf

[18] PJM is a US regional transmission organisation that coordinates the movement of wholesale electricity in all or parts of 13 states and the District of Columbia. See http://www.pjm.com/markets-and-operations/demand-response.aspx

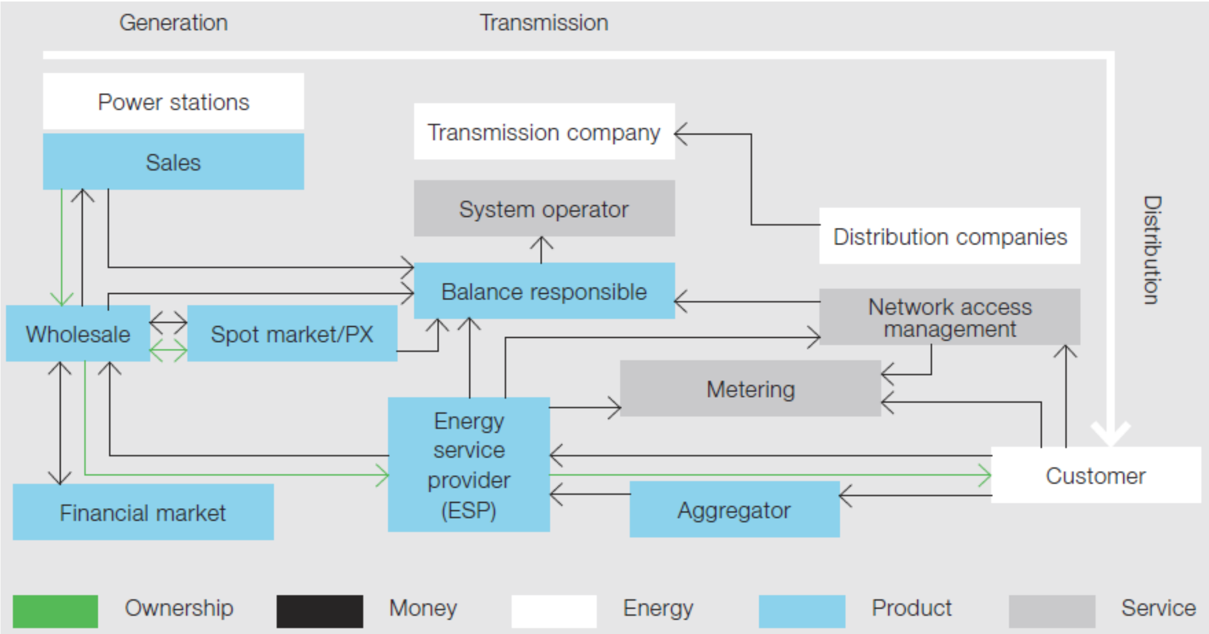


Figure 13: Technical and commercial roles in an electricity market with full retail competition. Source: ABB (2014)

5.1. Market design for demand response: overview of recommendations

Recommendations from SEDC (2014), EC (2015) and Eurelectric (2015) can be summarised as follows:

Demand response must be able to compete fairly in all electricity markets

One of the challenges for achieving cost-effective DR is that it is not treated on an equal basis with existing resources in all electricity markets: balancing, energy and capacity markets. It is therefore recommended to:

- **Remove market entry barriers** so that third party intermediaries can enter the market and provide DR services. This is particularly important, since not all consumers are able to bid directly on the market, and would only be able to contribute to DR if it is provided as a service.
- **Ensure the proper compensation/remuneration of demand response** so that DR can compete on equal terms with generation capacity, and to encourage innovation to diversify DR offerings in the markets. The SEDC recommends that DR services be compensated at the full market value of the service provided. Market-based valuation of DR also helps to avoid any extra cost to the systems, customers and other actors (Eurelectric, 2015).
- **Enable full participation** by ensuring that even small consumers are also able to participate in DR markets. This means, for example, that:
  - The participation of aggregated load, treated as a single unit, should be legal, encouraged and enabled in all electricity markets. As one example, Swissgrid has successfully implemented the so-called "Regelpooling" or "Control Pooling" concept together with the Swiss Association of Electricity companies (VSE), allowing for a non-discriminatory integration of DR into the Ancillary Services market[19].
  - Consumers should be able to contract with the aggregator of their choice without interference from their electricity supplier, or be able to switch suppliers when required.
  - Unbundled standard products that allow a range of DR resources to participate should be created.

[19] https://www.swissgrid.ch/swissgrid/en/home/reliability/power_market/control_pooling.html; http://regelpooling.ch/#

Incentive structures must be designed to foster demand response participation

- Efficient demand response requires **correct price signal on the supply side**; in many instances market prices are still low because of the subsidies to conventional power plants and/or the merit order effect of renewable energy technologies.
- **Costs and benefits allocation and remuneration of demand response should be fair**. Well-designed incentive structures can achieve effective coordination of different stakeholders. As such, Eurelectric (2015) suggests that "national regulators and system operators should oversee the creation of streamlined, simple contractual and payment arrangements between retailers, BRPs and aggregators. These should reflect the respective costs and risks of all participants."
- **Balance Responsible Parties/suppliers should be compensated for the energy they inject,** and that is re-routed by third party aggregators. To this end, the third party aggregator and supplier agree on the rules of compensation, and make provisions for settlement adjustments, e.g. in case of changes in market rules.
- **Creation of sufficient incentives for the market participation of DR**. This may, for example, require full implementation of **cost-reflective pricing** in order to create the price signals that will make it attractive for aggregators to set up the required DR infrastructure.
- **Performance metrics must be defined**, and penalties for non-compliance should be fair and not favour one resource over another.

Roles and responsibilities of different stakeholders must be clearly defined

Clear roles and responsibility must be assigned to market and system operators. Some examples are described below.

Aggregators

Aggregators are the key to the deployment of DR and have been a key driver behind the success of the DR story in the US (75% of DR in PJM is delivered by independent aggregators); they bring innovation and new technologies to the market. Aggregators must be allowed to stand in the place of the consumer and be able to operate independently of the supplier, i.e. the market model should not require a bilateral contract with the BRP, whereby BRP approval before the aggregator can offer a consumer's flexibility into the market. **A clear balance responsibility of the aggregator must be established**.

DSOs

Traditionally, DSOs have been responsible for meter reading and meter data validation. DSOs could therefore also act as data managers in new flexible power systems with DR, although this role could as well be taken up by third party players, e.g. centralised data hubs (THEMA, 2015). DSOs could acquire a new role in providing ancillary services by procuring loads from distributed energy sources (Eurelectric, 2015).

TSOs

TSOs traditionally provide ancillary services through procurement from large power producers. THEMA (2015) suggest a new role for TSOs to handle the financial settlement of imbalances and also for the development of data exchange platforms.

Balance Responsible Parties

In emerging power systems, all players connected to the grid are potentially 'balance responsible'. Eurelectric (2015) emphasizes that "overlaps or gaps of balancing responsibility must be avoided."

Market rules

Market rules that affect participation of demand response include (MacDonald et al., 2012):

- Rules that affect **resource size**, since these can exclude participation of many resources affecting business potential and competition
- Rules affecting **metering and telemetry**, as these affect capital investment required to enable a resource to participate in the market

- **Bidding timelines**, e.g. gate closure, rules, because they impact profit streams and exclude innovation by start-up organisations. For balancing purposes, gate closure would ideally be small to offer the system operators the benefit of more accurate system-wide forecasts (e.g. wind generation) as well as up-to-date information of the conditions of their own generation and distribution facilities.

Importantly, where rules are market specific, it must be ensured that they are harmonised to avoid incoherent or conflicting rules on the market as a whole.

Coordination mechanisms should be put in place

An appropriate coordination mechanism would need to guarantee:

- Adequate communication between third party aggregators and BRPs/suppliers to ensure that DR can take place effectively
- Information exchange between DSOs, TSOs and aggregators using, e.g. a system that reflects network availability
- Renegotiation. On a commercial basis, BRPs/suppliers should be able to renegotiate supply contracts to take into account the indirect effects of demand response (e.g. rebound effects) and consequent impacts on sourcing costs.

5.2. Market redesign for demand response: the French case

The observation of a gradual decrease in realised DR but increasing peak consumption in France since 2000 pointed to some regulatory and technical barriers to harnessing the potential of DR. Since 2010, France has taken a step-wise approach to open all the markets to DR based on the principle that **full participation of all DR resources is needed to unlock the full potential of DR** (RTE, 2014).

The French market reform involved:

1. Creating a level playing field between incumbent suppliers and independent DR operators by allowing all types of DR resources to compete in all markets as a power sector resource and through unbundling
2. Proper accounting of positive externalities, such as lower electricity prices, generated by DR by introducing a capacity mechanism
3. Developing adapted control methods to enable aggregation/pooling of small loads
4. Reducing barriers to independent DR operators' participation, e.g. through certification.

The different stages and impact of the French market design are illustrated in Figure 14. Today, France has systematically opened all electricity markets for DR (capacity, balancing, energy), and enabled independent aggregation to flourish (currently about ten aggregators are active in the market). But public support for DR (referred to as DSM in France) (Stage 4) has yet to be reached.

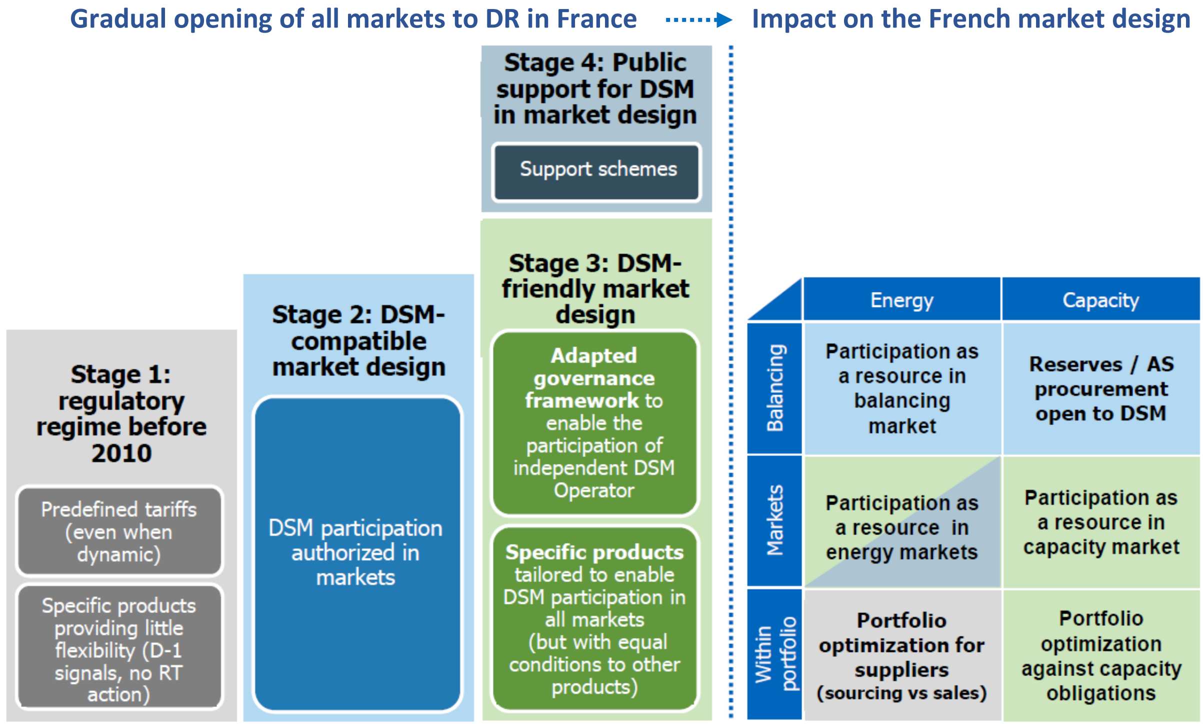


Figure 14: Different stages in French market reform and its impact on the market design Source: RTE (2014)

5.3. Common considerations and open issues

What are the market arrangements that are conducive to the development of DR?

- Who should be in charge of DR?

In a recent report by ACER (2014), it was suggested that an independent, neutral party should be in charge of constructing the routes to market and regulations affecting demand-side flexibility. This is because most market participants earn income by providing other sources of flexibility and are conflicted from a neutral approach to organising demand-side flexibility, as it is potentially prejudicial to their other financial interests.

This said, more than the identity of the 'DR manager', it is important to create market structures that not only reward and maximise flexibility and capacity in a market but also provide a stable market environment for investment.

DR compensation

- Eurelectric (2015) proposes three compensation models:
  - Corrected model: consumers' metering data are corrected by the amount of electricity that has been sold to the aggregator.
  - Regulated model: Direct compensation by the third party aggregator at a regulated price.
  - Contractual model: Third party aggregator and BRP/supplier agree on a compensation scheme.

None of these models, however, truly allows for market-based pricing of energy and flexibility, suggesting that there are possibly other compensation mechanisms.

- Demand response premium

It may be tempting to pay a premium to DR to promote its deployment, especially on the grounds that DR creates positive externalities and can improve social welfare. In this frame, externalities should be priced and paid out as a premium. But as with subsidies for renewables, it is bad economics if wrongly calibrated, e.g. due to information asymmetries and uncertainties regarding future efficiency improvement.[20] In the US, for example, DR can only be allowed if it passes the net-benefits tests, i.e. if DR can be issued in a cost-effective way.

DR as a market instrument in the Internal Energy Market (IEM)

It is important to ensure that all countries allow DR to participate in reasonably harmonised terms, in order to have a level playing field for DR throughout Europe. How this can be achieved given the different stages of DR development remains an open question. Likewise, it is not known to what extent DR and IEM are compatible.

Ancillary markets with real-time DR products

Traditional DR uses such as emergency load relief, system peak management are most often discussed. But, it has been conceptually shown that DR is also suited to provide ancillary services (e.g. Christakou et al., 2014). The main difference between traditional applications of DR and DR for AS are the reduction of notification time, and the speed and accuracy of measurement.

It is not known how much value can be extracted from DR for AS. Given its newness, how to characterise the market size of DR for AS? Can DR be implemented in ancillary markets under current regulation?

Capacity market design and DR

Capacity markets are established as a parallel market in addition to the 'energy-only markets' (Hogan, 2005; Hogan 2015). Capacity markets and programmes have been the main avenue for developing DR in the US because of the high summertime peaks that air conditioning creates. In Europe, capacity markets are mainly advocated because soaring intermittent renewables are displacing fossil fuel plants, so that they are no longer financially viable. As a result, there is often a lack of peak capacity. Capacity markets are thus designed to deal with the missing money problem.

A capacity program is a scheme that allows generation and demand-side resources to be paid in advance in promise for being available to meet future energy needs. Capacity markets are expected to open competition for DR to a host of players such as Energy Pool, EnerNoc, Honeywell and Kiwipower. In the future, one may see more virtual power plants, like the ones Siemens created with RWE or that ABB/Ventyx created with E.ON in Sweden or, more recently, by Arcelor Mittal and REstore in Belgium, bidding into capacity markets[21].

In spite of these developments, the effectiveness of capacity markets for demand response is yet to be proven in Europe. There are concerns that capacity market design ignore the contribution of interconnectors to security of supply (Newberry, 2015a). Furthermore, it has to be determined which of capacity payments and reliability options work best and how to design capacity auctions to avoid wasteful procurement of overcapacity (Newberry, 2015b).

[20] http://debate.tse-fr.eu/column/leffacement-de-la-prime-leffacement?language=fr
[21] http://www.greentechmedia.com/articles/read/capacity-markets-the-future-of-european-demand-response

6.
POLICY AND REGULATION TO SUPPORT COST-EFFECTIVE DEMAND RESPONSE

There is a consensus that a clear legal and regulatory framework is needed for demand response to take-off. Regulatory barriers, as in countries where DR is not allowed, or lack of enabling regulation are often considered as one of the key challenges for DR development.

In Europe, the SEDC has published a regulatory review of incentive-based demand response. Based on an extensive analysis, the document (SEDC, 2014) maps the extent to which the regulatory environment is favourable to the deployment of demand response in different European countries. The results, shown in Figure 15, indicate that France and Switzerland have the highest scores, followed by Belgium, Ireland, Finland and Great Britain. The underlying assumption is that the extent of demand response development is positively correlated with an enabling regulatory environment, which is assessed on the basis of four criteria:

1. Consumer access to DR aggregators or service providers
2. Adaptation of balancing market requirements to allow for DR participation
3. The existence of standards for measurement and verification
4. Establishment of appropriate DR remuneration schemes as well as penalties for non-performance, including standards for transparency and reporting.

Variability in DR development can also be due to differences in the electricity mix, availability of enabling technology as well as national differences in how EU legislation is translated into national policies and programmes.

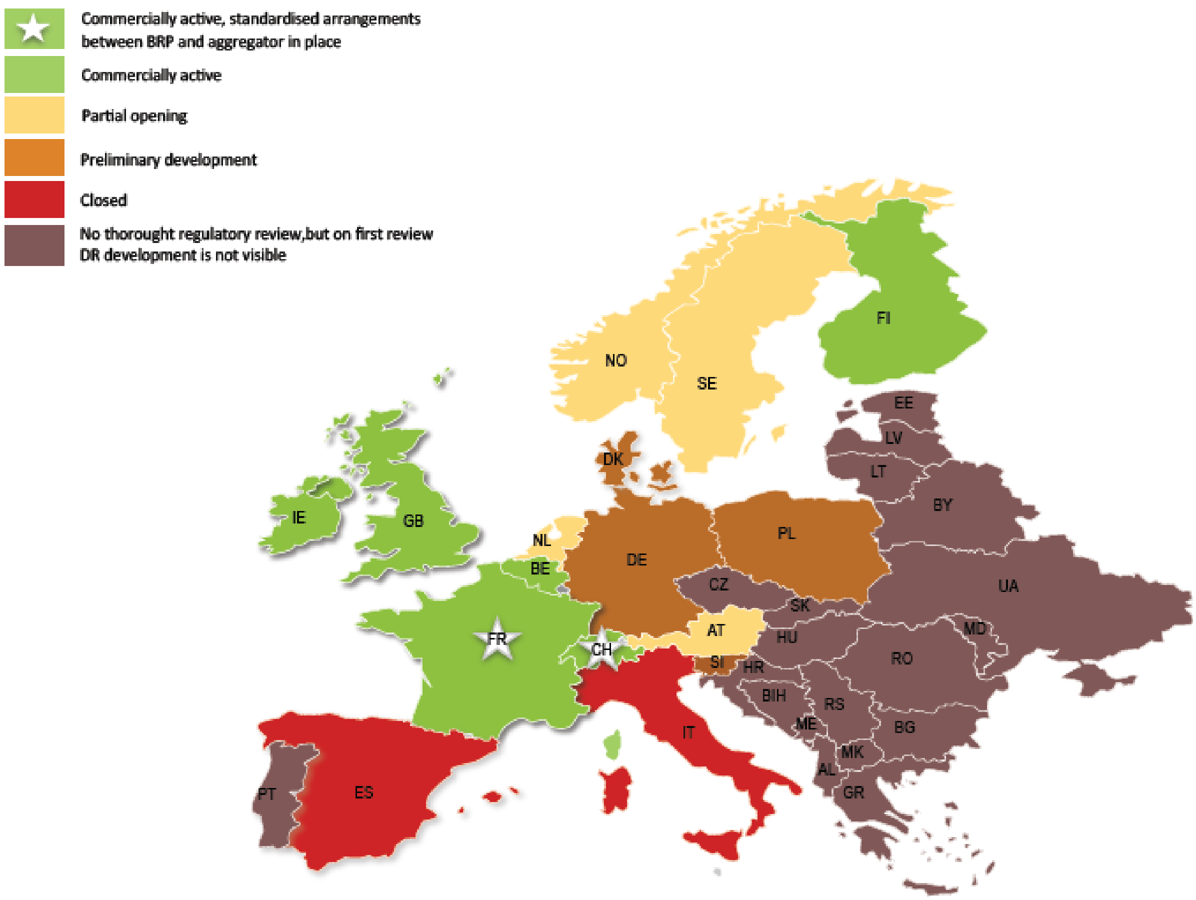


Figure 15: Regulatory review of incentive-based demand response in Europe. SEDC (2015)

6.1. Regulation and legislation surrounding demand response

Europe

- **Directive 2005/89/EC**

This directive concerns measures to safeguard the security of electricity supply and infrastructure investment. Specifically, it assigns the responsibility for ensuring the security of supply (SoS) to member states. Key provisions affecting demand respond include (i) support for new capacities necessary for SoS (Art. 5.2.a,f) and (ii) adoption of real-time management technologies (Art. 5.2.d).

- **Internal Market in Electricity Directive 2009/72/EC**

Art. 8 of this so-called 'Third Package' makes provision for tenders for new capacity, whether DR or generation.

- **Energy Efficiency Directive 2012/27/EU**

The European Energy Efficiency Directive emphasises the importance of DR as an instrument for EE. Art. 15.4 makes provision for removing incentives and tariffs that are non-conducive to DR participation. Art. 15.8. makes provision for DR participation in wholesale and retail markets, including access and participation of DR in balancing, reserves and other ancillary services markets alongside generation. It specifically includes aggregators.

- **European Network Codes**

European Network Codes, e.g. on electricity balancing, and the Demand Connection Code position DR as an important contribution to the system.

United States

- **The Energy Policy Act of 2005 (EPAct 2005)**

Section 1252(e)(3) and section 1223 provide a congressional mandate for demand response in organised wholesale markets and specifies the Commission's role to encourage the deployment of advanced transmission technologies, some of which implicate demand response and other distributed resources.

- **The Federal Power Act (FPA) of 1935**

Sections 205 and 206 and Sections 824D and 824E establish the Commission's authority over establishing just and reasonable wholesale power market rates.

- **FERC Order 719 and 745**

FERC governs wholesale energy market rates and factors affecting those rates. Order 719, established in 2008, removes barriers to demand side participation in organised wholesale markets. Order 745, established in 2011, requires uniform compensation at the locational marginal price for demand response suppliers who participate in the day-ahead and real-time energy markets.[22]

6.2. Recommendations for regulatory reform

- **Incentive reforms**

Setting adequate and state boundary conditions for DR compensation and participation, e.g.:

- Incentives to participate and penalties for those who neither participate nor take comparable actions
- Abolishment of fuel subsidies and gradual internalisation of external costs of fuel use, broadly defined
- Improvement of price signals to consumers.

[22] This provision has however been contested on the grounds that it based on misapplied economic principles. Specifically, FERC Order 345 requires that DR resources are compensated at the same locational marginal price as generation. However, DR does not involve a physical flow from the consumer to the grid and as such a unit of DR not consumed is not equivalent to a unit of generation.

Critically, various distortionary incentives persist in power systems. On the one hand, fossil fuels that are used by gas/coal baseload plants tend to be heavily subsidised (see e.g. IEA, 2014). On the other hand, feed-in tariffs that have been put in place to promote investment in renewables also distort markets and can potentially pre-empt the competitive development of DR. Specifically, by driving spot market prices down, feed-in tariffs reduce the economic value of DR.

- Technological reforms
  - **Establishing open and interoperable standards for interfaces**. Standardisation, for instance, is a huge issue in home automation. Developments such as the EEBus initiative in Germany[23], ZigBee and HomePlug Green PHY (AHAM, 2010) should be encouraged to facilitate fast establishment of standards such as in communications protocols, and thereby faster development of advanced forms of DR.
  - **Promoting smart appliances**. Recent body of work suggests that smart appliances could contribute towards facilitating DR implementation (Bilton et al., 2014; Wilkenfeld, 2011). In this light, new regulations may be needed to ensure appliances include built-in DR controls to help lower the costs associated with DR deployment as in Home Energy Management Systems (HEMS)[24].

- Institutional and market reforms
  - **Unbundling of generation/distribution and demand response services for optimal distributional effects.** Independent DR service providers (or 'pure players') need to access the market to directly value load reduction in energy/capacity markets (i.e. make an explicit valuation) and also compete with suppliers to value flexibility in the markets (i.e. implicit valuation). For such competition to take place, aggregators must be able to operate independently of the supplier. This also ensures that the consumer is truly able to choose the best option for supply and for demand response.

From a regulatory point of view, unbundling is based on two complementary requirements:

1. **Aggregators should have free access to consumers**, i.e. an aggregator should not have to ask the authorisation of the supplier to operate. This means that the market design should foreclose contracts between aggregators and suppliers or BRPs.
2. **Provision for confidentiality of commercial activities**. Independent aggregators and suppliers are potential competitors in finding flexibility resources and convincing consumers to participate in DR. Ensuring the confidentiality of the aggregators' commercial activities is crucial to ensure a level playing field.

   In France, for example, both issues have been dealt with recent legislative and regulatory acts, which have required intense work from the public authority, regulator, TSO and market parties.

6.3. Timing of regulatory reform in view of innovation and stability concerns

An important question concerns the optimal timing of regulatory reform to facilitate the development or the further deployment of DR. Some stakeholders are concerned that DR deployment may be stymied by delays in regulatory reform and opportunities associated with DR deployment may be lost.

In the context of energy transitions, the case for early regulatory and policy intervention is closely linked to the fact that the electricity sector is undergoing a major transformation with a new energy mix. This transition challenges the established microeconomic foundations of the power sector – with energy supply following energy demand, and many actors look to regulation to provide some direction. For example, the market and the overcapacity of renewable and conventional generation *in some countries* is one challenge for DR. Herein, there is a clear role for regulation to provide a roadmap in line with policy targets to ensure that DR resources are available when the intermittent renewable resources hit a certain threshold.

[23] http://www.gridinnovation-on-line.eu/Articles/Library/SmartWatts--The-EEBus-Standard--Development-And-Benefits.kl
[24] The 2013 Smart Grid Advancement Act in the U.S. points to such a development: http://www.gpo.gov/fdsys/pkg/BILLS-113hr2685ih/pdf/BILLS-113hr2685ih.pdf

But, it is also often acknowledged that regulation can slow down innovation or create a lock-in to sub-optimal standards or arrangements by intervening too early. In such instances, regulators may prefer to delay intervention in the market and leave it to relevant stakeholders to establish standards, and/or develop contractual arrangements that are most befitting. As it is, good regulation is based on proper information, which may be lacking at the time.

At the EU level, Torriti et al. (2010) noted that "Developments in DR vary substantially across Europe reflecting national conditions and triggered by different sets of policies, programmes and implementation schemes." They further highlighted that "coordinated DR policies have been slow to emerge […] because of the limited knowledge about DR energy saving capabilities; high cost estimates for DR technologies and infrastructures; and policies focused on creating the conditions for liberalising the EU energy markets."

It is therefore important to take an integrated perspective sufficiently early. And, given the increasing interdependencies across infrastructures (e.g. because of complementarity of technologies) and actors as well as intertemporal nature of power sector R&D and investments, new and innovative governance arrangements may be necessary to deliver timely and coherent policies for DR development in view of maintaining or enhancing grid reliability and facilitating energy transitions.

7.
QUESTIONS FOR RESEARCH AND TESTING

This overview of demand response has highlighted a number of gaps in knowledge about DR, which research on the following topics could help address:

Risk governance of power system transformations

- **To what extent is demand response a viable option for power system flexibility?**
  - How to select and prioritise flexibility options to facilitate energy transitions?
  - How to decide on the appropriate types of demand response? Is it possible to identify a hierarchy of actions?

- **How to evaluate the impacts of demand response on the electricity system as a whole?**
  - How can society get the full benefit of DR across time and resources?
  - The nature of the grid is evolving towards an architecture where smart grid networks and super grids will co-exist. How will this change the portfolio of DR offerings and what will be the costs and benefits?

- **Does demand response enhance social welfare?**
  - What are the costs, risks and benefits for the different actors in DR transactions?
  - How to avoid potential adverse distributional effects?
  - What is the overall social welfare impact of demand response?

- **How will the grid evolve in the future?**

It is quite likely that there will be uneven and incremental evolutions, involving smart meters, smart grids and super grids. Local/national smart grids are needed to aid local balancing of variable supply and demand. Supergrid would be pricey and would not be used all the time.

  - But which of super grids or smart microgrids provide the best balancing capacity?
  - Renewable electricity is often shunted around national grid systems. How to move beyond national concerns?

Realisable potential

- **Quantification of demand response potential**
  - What are the best practices for quantifying demand response potential across different sectors?
  - How much of demand response achieved is true, demand response vs. backup generation? What is the true potential of flexible demand and 'on-spot' or real-time demand response?
  - How will the demand response supply curves for different products/programmes shift over the years? What are the main drivers?

- **Design of large-scale pilot studies and demonstrations projects**
  - How to recruit classes of consumers for large-scale DR projects to ensure representativeness, scalability and replicability?
  - How to move from demonstration to the deployment phase?

- **Measurement and verification: how to avoid gaming risks?**
  - Is advanced metering infrastructure a necessity or will well-designed incentive contracts be enough?
  - Are standards for measurement and verification needed? If so, what are the key design considerations? And, how to enforce the standards?

Consumer engagement

- What are the best practices for engaging new consumers and how to successfully manage long-term engagement?

- How to assess the cost-effectiveness of different enrolment strategies and incentive structures?
- What are the pros and cons of integrating DR and EE programmes?
- What are the preferences and motivations and consumers who engage in demand response? If consumers are not willing to participate, what are their motives?
- How can incentives be formed to increase consumer participation in demand response? Can behavioural insights be used to trigger behaviour change?

Business models

- Which business models are most likely to demonstrate the profitability of demand response for each of the involved stakeholders? What are their key drivers?
- Is it possible to identify archetype business models, and which ones are likely to grow?
- How can DR service providers, whether incumbent utilities or new entrants, maximise the value of their DR programmes through business model innovation/adaptation?

Market design

- Roles and coordination of intermediaries with incentives for demand response expansion
  - What are the evolving and new roles of different intermediaries in the DR market?
  - How best to integrate new, innovative players, such as aggregators, into the market?
  - How to compensate different types of demand response?
- Evolution of demand response in different markets
  - What are the opportunities and challenges for the development of DR in ancillary services markets?
  - How can capacity markets contribute to the competitive development of DR?
  - What are the economic returns of demand response under different market arrangements?
- How to choose the best market design given different policy objectives and potentially conflicting goals of different power system stakeholders?

Regulation

- Given the changing nature of the power systems (new resources, new players, new product offerings), how to ensure that the regulatory framework remains fit-for-purpose?
- Establishing new legislations and regulatory acts take time and require extensive consultation with diverse stakeholders. How can processes be streamlined so that reforms are implemented in a timely and coherent manner?
- Which policies, addressing either technological or non-technological barriers or both, will allow for more widespread adoption by different stakeholders or DR?

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APPENDIX

Risk Governance of Demand Response in the Context of Energy Transitions

Conference and workshop, 10-11 September 2015, EPFL

Various countries in the world consider or implement demand response programmes, as activities that hold the potential to facilitate the transition towards sustainable energy systems. IRGC and the Energy Center aim to shed light on the following questions:

- Is it worth engaging in demand response programmes? Is adding flexibility on the demand side a viable alternative to additional generation capacity?
- If so, how to successfully deploy demand response programmes? How to assess and manage the risks involved?

Public Conference, Thursday 10 September, 09:45 –17:00

Demand Response: Overview of Advances and Trends

- Importance of demand response for secure and sustainable electric grids
- Risks and opportunities of different approaches to demand response
- Key enablers and barriers for realizing the demand response potential
- International experience: best practices and open issues

Follow-Up Expert Workshop, Thursday 10 Sep 18:00 –19:00 & dinner, Friday 11 Sep 08:30–16:00

The workshop will address the following themes, including relevant data and case studies, from a risk perspective

Realizable potential

- Empirical evidence of demand response gains across different sectors and countries
- Tools and methods for improving quantification of demand reponse potential
- Impact of peak shaving on total energy consumption, including rebound effect

End-user behaviour

- Understanding consumer behaviour and heterogeneity: elasticities, switching behaviour, sectoral differences
- Best practices for engaging consumers in demand response programmes
- Promoting benefits of smart meter rollout and addressing privacy risks

Business models

- Emerging business models for different market segments and regulatory contexts
- Innovations for bridging the gap between wholesale commodity market and retail services
- Key entry points, growth areas and investment timing in view of technological developments, e.g., distributed generation and storage

Regulatory aspects

- Overcoming regulatory barriers to the successful deployment of demand response
- Optimal governance of electricity sector in view of microgrid development
- Regulatory framework for demand response oversight in integrated energy markets

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ABOUT IRGC

The International Risk Governance Council (IRGC) is an independent non-profit foundation with an aim to help improve the understanding and management of risks and opportunities by providing insight into systemic risks that have an impact on human health and safety, on the environment, on the economy and on society at large.

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