POLICY BRIEF

DEMAND-SIDE FLEXIBILITY FOR ENERGY TRANSITIONS

Policy recommendations for developing demand response

EPFL
ÉCOLE POLYTECHNIQUE FÉDÉRALE DE LAUSANNE
ENERGY CENTER

irgc
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PREFACE

Transition to low-carbon and renewable energy systems—from the shutting down of high-emitting power plants to the deployment of both large-scale and distributed wind and solar—is driving unprecedented changes in power systems. In particular, the increase in electricity supply variability calls into question the traditional approach of balancing electricity demand and supply by relying only on supply-side resources, such as imports, peak and flexible generators, and pumped-hydro storage. Adding more flexibility on the demand side, via demand response, is emerging as an important tool to optimally support a power system with increased supply-side variability.

Demand response (DR) is a set of demand-side activities that provide an array of grid balancing services, including equilibrating demand and grid losses with supply. Because DR can facilitate the integration of renewable energy sources, marked by intermittency, there is also widespread consensus that DR can reduce the carbon-intensity and cost of power systems. Yet, the deployment of DR is stymied, in large part, by market and regulatory barriers as well as technological uncertainties, particularly technological developments, such as electrical energy storage, which can either complement or compete with DR.

In the European Union (EU) the importance of DR is reflected in EU Directives. In the United States (US) the Energy Policy Act of 2005 and specific Federal Energy Regulatory Commission (FERC) rulings set the basis for DR. Furthermore, non-profit organisations such as the Smart Energy Demand Coalition (SEDC) in Europe, and the Association for Demand Response and Smart Grid (ADS) and the Advanced Energy Management Alliance (AEMA) in the US advocate the development of DR.

DR must be developed competitively, since it involves a continuum of options and actors, and its deployment may generate a variety of risks, e.g. investment and regulatory risks, as well as short and long-term power-system risks. The perceived benefits of DR also vary depending on the stakeholders' standpoint. Adopting a risk governance approach to DR deployment is recommended to better gauge the risks and benefits, and thereby to evaluate the extent to which demand response is a viable alternative to investment in conventional peak capacity and grid reinforcement, and to unlock barriers to its competitive development in an evolving power system.

It is against this background that IRGC, together with the EPFL Energy Center, organised a multi-stakeholder conference and an expert workshop on September 10 – 11, 2015 to shed light on the opportunities and challenges for demand response and to identify potential solutions, and published a report on "Demand-side Flexibility for Energy Transitions: Ensuring the Competitive Development of Demand Response Options," available at https://www.irgc.org/issues/energy-transitions/demand-response/.

This Policy Brief synthesises the key outstanding issues regarding the use of DR, focusing on the context of energy transitions in Western Europe. It is intended for an audience of policymakers, regulators and industry, who contemplate DR development. Based on international evidence, it urges early consideration of DR, since the implementation of policy reforms as well as the redesign of electricity markets take time.

ACRONYMS

ADR	Automated Demand Response
BRP	Balance Responsible Party
CAPEX	Capital Expenditure
CO_2	Carbon Dioxide
C&I	Commercial and Industrial
DLC	Direct Load Control
DR	Demand Response
DSO	Distribution Service Operator
FERC	Federal Energy Regulatory Commission
GWAC	GridWise Architecture Council
ICT	Information and Communication Technology
LMP	Locational Marginal Price
OPEX	Operating Expenditure
PV	Photovoltaic
SEDC	Smart Energy Demand Coalition
US AEMA	US Advanced Energy Management Alliance
TSO	Transmission System Operator

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SUMMARY

The Policy Brief highlights that increasing flexibility in power systems is needed to accommodate higher shares of non-controllable and intermittent renewable generation, and that this requires changes to the market design and regulatory framework, to facilitate the development and deployment of appropriate technologies and market-based instruments (e.g. taxes and subsidies). The Policy Brief focuses on demand response (DR), since it is emerging as a powerful demand-side energy management option to deliver flexibility.[1] Specifically, DR contributes to reducing overall electricity consumption or shifting demand in such a way that consumption better follows generation, particularly intermittent wind and solar. In point of fact, experts portend that DR could have avoided German utilities huge losses (half a trillion Euros[2]) when, on June 16, 2013, renewable generation exceeded demand and market prices went negative. Furthermore, DR can provide ancillary services for real-time power, frequency and voltage regulation.

In the European Union (EU) and the U.S., the importance of DR is reflected, respectively, in the EU Directives—particularly the Electricity Directive (2009/72/EC) and the Energy Efficiency Directive (2012/27/EU) —and in the U.S. Energy Policy Act of 2005 as well as specific FERC rulings (e.g. FERC Orders 719, 745, 755 and 780). The FERC Order 745 was recently upheld, allowing DR operators to pay DR participants the same rates for reducing energy use during peak demand hours as those paid to generators. In Europe, EU Directives remain to be transposed into national laws in many EU states. To address reliability risks due to growing peak demand, France has successfully redesigned its market to actively promote DR to address both peak capacity constraints and market liquidity constraints. An important lesson from the French case is that to be DR-ready and avoid missed opportunities, countries should initiate the redesign process as early as possible, because this can be a complex and lengthy process.

Demand response overview

Enablers of demand response

Technological advances, particularly in information and communication technology, underpin the maturation of DR from a basic peak reduction resource to one providing a full spectrum of grid balancing services. And, besides enabling regulatory and policy changes, the emergence of active consumers, aggregators and DR advocacy groups have created a need for more competitive electricity service offerings, in which DR is a low-hanging fruit.

Benefits of demand response

DR is highly lauded for its potential to reduce CO_2 emissions through enabling penetration of intermittent renewable sources, particularly by reducing the need for peak and flexible conventional generators, mostly gas-fired power plants. DR can also bring economic benefits in the form of revenues for services to the grid and potential investment savings in electricity generation, transmission and distribution assets. DR has the potential to create broader value to society by increasing competition and innovation. Furthermore, as end-user behaviour co-evolves with DR and new technologies, additional social value will be catalysed.

Evolution of demand response

The development of DR across the world is rather varied, depending on country-specific system needs and barriers to deployment. The U.S. has been and still is the leader in DR. Over the next decade, the highest DR growth rate is expected in Asia Pacific. Growth will be registered in both the Commercial and Industrial (C&I), and residential consumer segments, but the latter will still account for only a small share of the market. While DR has been primarily used for shaving peak loads, it is increasingly valued for the provision of a wider range

of grid services, namely power, frequency and voltage regulation, which are needed to allow for increasing reliance on variable renewable resources.

- Barriers to demand response

The growth of DR is stymied by uncertainty regarding the feasible potential of DR, due to uncertainty about the technical constraints to delivery DR when called, the economic value of DR as well as the extent to which consumers will be engaged in DR activities. Furthermore, transaction costs borne by DR participants and DR service providers are currently too high and preclude the participation of many actors and resources. Besides, incumbent utilities that have traditionally provided flexibility from conventional power plants may resist DR or lobby against the equal treatment of DR vis-a-vis supply-side flexibility.

Recommendations: key levers to facilitate DR development

DR should be recognised as one constituent of power-system flexibility alongside other traditional flexibility resources such as flexible generation, power storage and network upgrade. Yet streamlining DR in low-carbon power systems involves lengthy processes of regulatory, market design, and governance changes. The following five key levers can facilitate the timely and competitive DR development.

Redefining roles and responsibilities. Incumbent utilities perceive electricity market entrants such as aggregators as a threat to their businesses. In this context, it is important to specify clear framework conditions for DSOs to evolve their role and foster collaboration and strategic partnerships to leverage their coordinating role in electricity markets. Furthermore, the responsibility for addressing grid imbalances should be increasingly borne by those generators—including wind and solar—that cause the imbalances.

Enabling dynamic and transparent pricing. Pricing is an important element of the market design that enables business models to unleash DR capacity, extract and distribute the associated value. Prices have to be deregulated to enable the capture of the full potential of DR. In particular, electricity should increasingly be priced at locational marginal price, while auctions for DR should be encouraged to ensure efficient price discovery for DR.

Lifting market entry barriers. Regulation and policy can provide further impetus to DR by deregulating and opening markets so that all resources (from both the demand-side and supply-side) and actors (incumbents and new entrants, alike) can compete on equal terms. Streamlining approval procedures and requirements will reduce transaction costs and open market access to broader range of DR resources. It is equally important to manage the sequencing of market opening for a smooth and sustainable transformation of power markets.

Harmonising policies. Regulation should encourage a shift away from capital investment in conventional generation units for flexibility provision, and harmonise incentives so that different sources of flexibility, including DR, can be synergistically developed. Distortionary subsidies to coal should be removed, for instance. Given the need for DR to cost-effectively enhance security of supply, in the case of Europe, adequate provision for DR should be made in the Network Codes to ensure its timely deployment.

Adopting a risk management approach. A three-pronged risk management is required. It involves first promoting the use of standardised tools for robust evaluation of DR potential. Second, the risks and obstacles to the delivery of DR should be assessed and addressed upfront. Third, any residual risk, e.g. risk of unscheduled supply disruptions, should be addressed via contractual risk transfer mechanisms.

1. INTRODUCTION

The transition to a low-carbon society, in general, requires higher penetration of variable renewable generation (wind and solar), both at centralised (utility-scale) and distributed (local) levels. Wind and solar electricity are highly variable and non-controllable weather-dependent output. Their integration entails unprecedented power sector challenges, pertaining to the intermittent power availability over hourly, daily and seasonal timescales, as well as frequency and voltage variability over the sub-second time scale. Addressing those challenges requires a full spectrum of flexibility options. The need for flexibility is not new. It has been traditionally deployed to address demand variability and uncertainty, as well as power plant and grid contingencies. Controllable power plants—mostly gas-fired plants and hydro dams—have been used to that end. However, it is inefficient and very difficult to meet the flexibility needs of intermittent resources from these supply-side resources only. In this context, adding flexibility on the demand-side through demand response (DR) is emerging as a highly lauded and cost-effective option for grid balancing across both temporal and geographical scales.

DR consists of temporary shifts in electricity consumption in response to price signals or other financial incentives, or in reaction to grid conditions. Its early deployment aimed primarily at avoiding outages due to insufficient capacity during peak demand periods. This form of DR is often referred to as peak-shaving DR. Since 2010, in response to increasing shares of variable renewable electricity generation, DR has matured into a resource that can provide an expanded range of grid services, such as ancillary services for (i) power quality through grid stabilisation and renewables capacity firming, (ii) improved power reliability through contingency response, and (iii) better utilisation of grid and generation assets, through peak shaving, load leveling and load-following DR (see Figure 1).

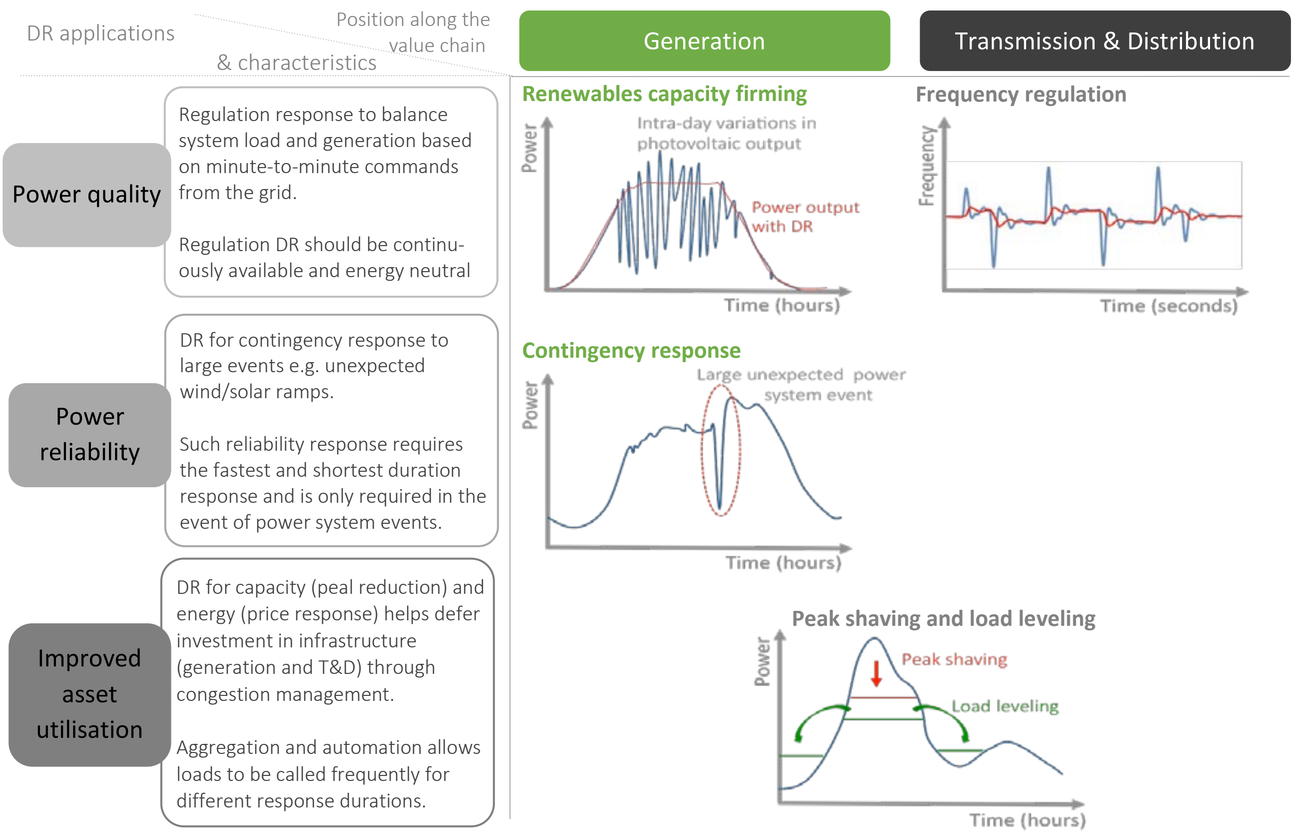

Figure 1: Conceptual illustration of key demand response applications and benefits. Source: Adapted from different sources.

1.1. Benefits of demand response

As a flexibility resource, DR has a number of advantages compared to other flexibility options, such as peaking plants, storage and network reinforcement, particularly by leveraging the synergies between other flexible resources as well as market operations (see Figure 2).

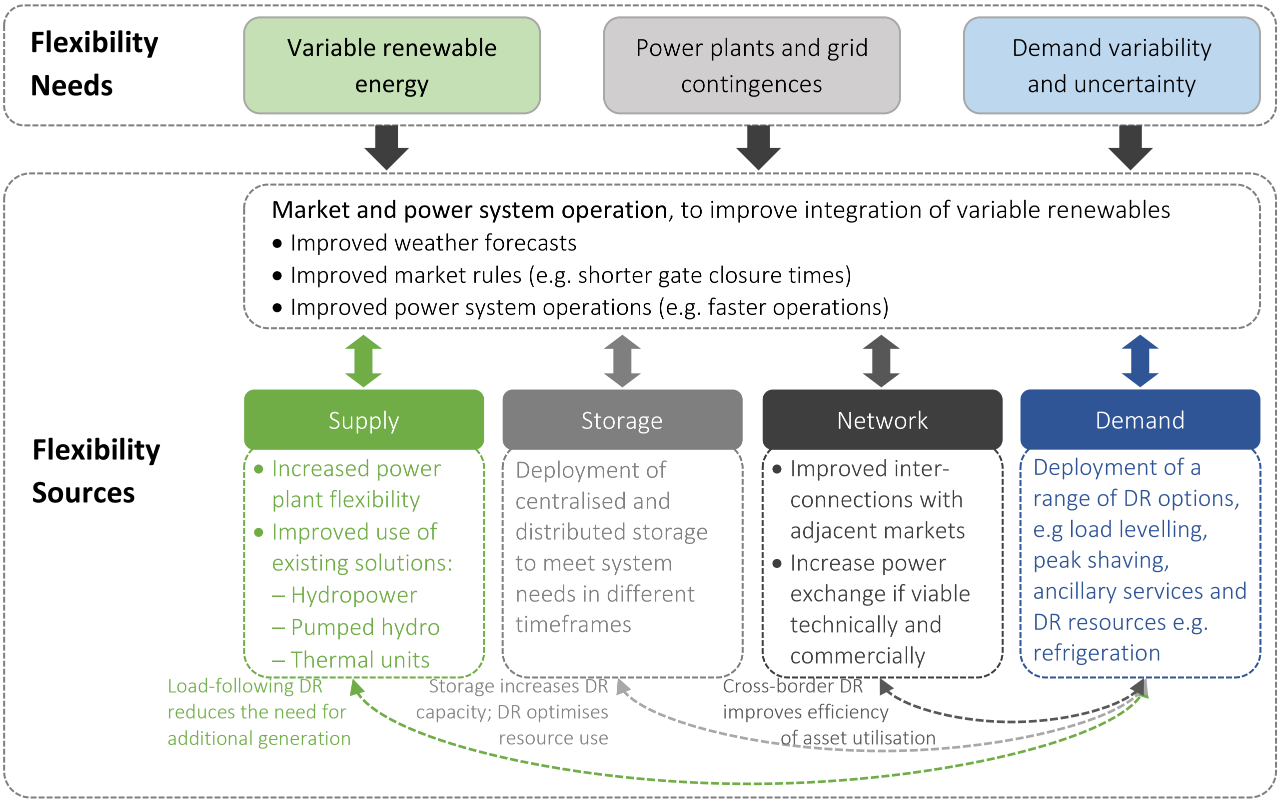

Figure 2: The need for flexibility and the role of demand response vis-à-vis other flexibility sources. Source: CEN analysis.

Demand response contributes to power system decarbonisation

DR contributes to reducing overall power system emissions by displacing high-emitting generation units that provide baseload and peak capacity, and ancillary services. The CO_2 impact of DR is proportional to the carbon intensity of the curtailed load in case of peak-shaving DR. In the case of ancillary services, DR displaces fossil-based generation units that are dedicated to providing operating reserves and regulation services. These units do not operate at the 7000-8760 full-load hours per year but are run at part load—ramping from 10% to 100% intradaily, depending on system needs—and emit more CO_2 as a result. DR for ancillary services enables a more efficient dispatch of these generation units, lowering emissions.

Furthermore, DR helps to absorb renewable generation peaks and troughs via shifts in consumption, which consists in increasing electricity consumption when renewable generation is high and vice versa. This is known as load-levelling or load-following DR. It reduces the reliance on baseload and peaking units. The resulting emissions reduction is proportional to the amount conventional power generation displaced.

A 2014 study by Navigant Research[3] estimates that these different forms DR could, together, help remove about 40 million metric tons of carbon emissions in the United States. In Europe, a collaborative study conducted in 2008[4] estimated that DR could contribute up to 25% of EU 2020 target for CO_2 emissions reductions (i.e. 100 metric tons) should DR receive full support from EU member states and all relevant stakeholders. Otherwise, only a third of this potential would be captured.

Demand response is cost-effective from a power system perspective

DR is a cost-effective dispatchable power system resource, often requiring little additional investment.[5] By contrast, peaking power plants and flexible generators are capital intensive solutions that are only used infrequently when the grid is under stress, resulting in very expensive production cost per kilowatt-hour (kWh) and low-profitability. As a result, these generation units do not appeal to investors, raising the risk of peak and operating reserves capacity shortage. This problem is exacerbated by the decline in wholesale electricity prices that has accompanied the policy-induced deployment of intermittent renewables. In view of the prevailing dearth of sufficient peak and flexible capacity (except for few countries like Germany, Netherlands and Switzerland), many European countries such as France and Belgium have turned to DR.

DR can furthermore substitute for network upgrade at least in the short run. Grid reinforcement is expensive and involves a high lead-time. It is also limited by social acceptance such as the Not In My Backyard (NIMBY) Syndrome. Wind and solar, due to their frequency and voltage fluctuations and intermittency, exacerbate constraints on existing transmission and distribution networks. Together with limitations on network upgrade, increasing wind and solar make active grid management an imperative. DR protocols can be used to that end. DR has been shown to be deployable cost-effectively using existing communication infrastructure.[6] DR's contribution to active grid management should therefore become an integral part of network infrastructure planning. In effect, including DR considerations in long-range network and resource planning could help on two fronts, namely operational risk management and system resilience planning.

DR can also be used for cross-border balancing; its potential can be gauged from the 2014 Danish DR event. On July 9 2014, Denmark produced more than 100% of its electricity demand from wind farms. Cross-border DR, through interconnectors, made it possible to reduce renewable curtailment: 80% of the surplus was sold to Norway and Germany to be stored in their hydropower systems for later use. To unleash the full potential of this form of cross-border DR, it will be necessary to invest in additional physical infrastructure, especially high-voltage transmission lines, to accommodate the flows of power, and also to change market design to enable the economic transaction.

DR boosts competition and innovation in the power sector

DR involves a paradigm shift in the operation of power systems, whereby flexibility from conventional plants is replaced by shifts in consumption. The skills required for deploying DR differs significantly from operating traditional power plants, and are often lacking among incumbent utilities. From the beginning, DR development has been due to aggregators, such as ENERNOC.[7] Increasingly, information and communication technology (ICT) providers and incumbent utilities, which are under the pressure to deliver flexibility optimally, are also developing DR capabilities. The growth of players entails more competition, which in turn, boosts innovation as the players try to differentiate themselves to retain or capture new consumers.

1.2. Loads that provide demand response

There are at least four types of loads[8] that can deliver DR. First, **optional loads** relate to appliances that can operate at either full or limited capacity, and are typically controlled automatically, such as light dimming. Second, **deferrable loads** rely on consumers' choice to adapt the consumption of an energy service (e.g. when to use the washing machine) to the state of the grid, e.g. through a price signal.[9] Third, **controllable loads**, e.g. thermostatically controlled loads from air conditioning and refrigeration units, absorb excess wind and solar electricity, effectively cooling slightly below the desired temperature. Thereafter, the units stop consuming electricity until the temperature reverts to the desired level.[10] Fourth, an emerging class of load are **storage loads**, from electric car batteries to non-hydro utility-scale storage.[11]

These different loads must be integrated in a synergistic way to derive the maximal value from DR, since the ability of loads to provide different types of DR (load shedding, fast DR for frequency and voltage control) depends on the physical properties of loads and on end-users' behaviour. For instance thermostatically controlled loads are hysteretic, which imply that their availability for DR depends on its past and present state, e.g. a refrigeration unit that is in "on-state" cannot be switched off if the previous state was in "off-state." This hysteretic property also limits their effectiveness for fast DR, needed to respond to sudden changes in e.g. solar irradiation or frequency and voltage control. Relatedly, the ability of electric cars to provide grid-balancing services depends on the parked ratio. Presently, for real-time grid balancing services, large-scale storage in hydro-dams is the only mature technology, but utility-scale batteries are emerging as a proven technology. In addition, DR that uses distributed loads as well as distributed battery packs are increasingly being developed.

1.3. Enablers of demand response

While DR exists since the 1970s in basic forms, DR is receiving new impetus from a number of developments, namely (i) technological advances, (ii) conducive regulation and policy, (iii) cooperating consumer behaviour, (iv) new energy contracting, and (v) DR advocacy groups and pioneers.

- Technological advances

Technologies that connect the digital and physical worlds render DR non-disruptive for electricity consumers, and increasingly accessible to a wide range of actors, who can make efficient use of information technology to deploy DR for maintaining power reliability and grid stability. This is possible because the physics of the grid has not evolved as much as the new possibilities afforded by the integration of information and control technologies and other technologies for new ways to operate the grid.

At the local level/scale, advances in ICT underpin the development of advanced Demand Response Management Systems such as Home/Building Energy Management Systems and flexibilisation of operations in a number of industries, e.g. energy-intensive cement industries. At the grid scale, the IEA Smart Grid Roadmap[12] highlights that the integration of energy flow and information flow creates a new hybrid reality, characterised by a permanently evolving electrical network, with real-time, two-way flow of energy and information, between power generation, grid operator, and end users. This hybrid system is capable of integrating all traditional and new players: renewable generation units (wind and solar, whether centralised or decentralised), electrical vehicles, electrical storage and, thus, paves the way to smarter power systems.

Importantly, smart power systems provide better visibility on consumption and distributed generation helps improve forecasts (minimize forecast errors) and two-way real-time communication assists DR in improving the optimisation of resources for reliable power-grid operations over time.[13] Many of these digital developments are being catalysed by innovation in power electronics and electricity storage. In parallel, progress in security and communication standards facilitates large-scale automated DR (ADR) deployment. DR provides grid stabilisation services using and/or leveraging loads from different resources such as batteries and heat pumps, as well as new infrastructures such as smart charging infrastructure for electric vehicles.

- Regulation and policy

A considerable number of policies and policy instruments, whether regulatory (e.g. laws, regulations and standards) or economic (e.g. taxes and subsidies) already have strong bearings on the governance of the power sector, from its day-to-day operations to long-term strategic decision-making. Stimulus packages for advancing DR development have been introduced in countries such as U.S., United Kingdom (UK) and France. In the EU and the U.S., the importance of DR is reflected, respectively, in the European Directives—particularly the Electricity Directive (2009/72/EC) and the Energy Efficiency Directive (2012/27/EU)—and in the U.S. Energy Policy Act of 2005 as well as specific FERC rulings (e.g. FERC Orders 719, 745, 755 and 780). They aim at removing barriers and establishing rules for DR. These policies have to evolve to account for behavioural changes, e.g. increase in prosumerism, and adapt to institutional developments, e.g. retail price deregulation.

- Changes in consumer behaviour

Consumer behaviour is slowly but steadily shifting in favour of DR. Price-sensitive consumers look for competitive prices and are willing to switch electricity providers and engage in DR if it entails financial savings with limited administrative burden. “Green” consumers, who actively seek to contribute to CO_2 reductions, modify their consumption patterns, turn into producer-consumer (prosumer) and aim to adopt electric cars. These early adopters, through peer or network effect, are critical for DR to diffuse more broadly. Maturation of DR will happen when consumers have a better understanding of the impact of their consumption decisions and of how they can take control of their service and associated costs.

- New energy contracting

The power industry is undergoing a transition towards proactive value-based energy services. This is driven by a number of developments in the electricity market that are putting traditional utilities’ business model, based on sales volume, under pressure. First, the shift in generation mix towards less controllable resources is either triggering or exacerbating grid reliability issues, driving down consumer satisfaction. Second, with increasing shares of wind and solar, margins in electricity markets keep eroding. Third, there is regulatory pressure of kilowatt savings on large consumers. Fourth, utilities are facing competition from new entrants such as aggregators and ICT providers.[14] In this context, DR can be the piece of the puzzle to enable utilities to develop new value propositions for their customers, and secure sustainable revenue streams.

- Demand response advocacy groups and pioneers

Urges for DR-related reforms come primarily from advocacy groups, such as the U.S. Advanced Energy Management Alliance (AEMA) and the Smart Energy Demand Coalition (SEDC) in Europe. These advocacy groups have emerged to represent DR on policy fronts, in part, because incumbent utilities, which start losing revenue to DR providers, can exercise their market (and political) advantage to protect their interest (see Section 3.6). This includes utilities that have come to grip with the fact that DR and other demand-side resources could boost their profits by providing greater visibility on the entire power system value chain, offering an opportunity to improve power grid operations. The advocacy groups aim to preserve the integrity and competitiveness of the entire DR industry, helping unleash the full potential of DR and protecting the interest of small players and new entrants. Increasingly, TSOs are also initiating or pressing for reforms to enable faster DR deployment. Notable examples include the French TSO, the Réseau de Transport d’Electricité (RTE) and U.S. regional transmission operator, PJM Interconnection. These actors have recognised that some power market redesign is needed so that DR can be considered as a genuine resource by the market, especially in light of a historical legacy in which demand has consistently played a passive role, with utilities having to ensure sufficient capacity to meet demand, in a load-following way.

2. DEPLOYMENT STATUS AND POTENTIAL

DR development and deployment pathways are diverse, reflecting country-specific power system challenges, and DR penetration is currently very heterogeneous across consumer segments and electricity markets.

Figure 3 below shows the DR trends in world markets. The U.S. is the current leader of demand response globally. As other countries are either introducing or expanding DR programmes, this leadership position is likely to be eroded over the next 10 years according to a Navigant Research study.[15] It projects that global capacity for DR will grow from 31 GW to about 200 GW between 2014 and 2023, with the largest growth coming from Asia-Pacific, followed by

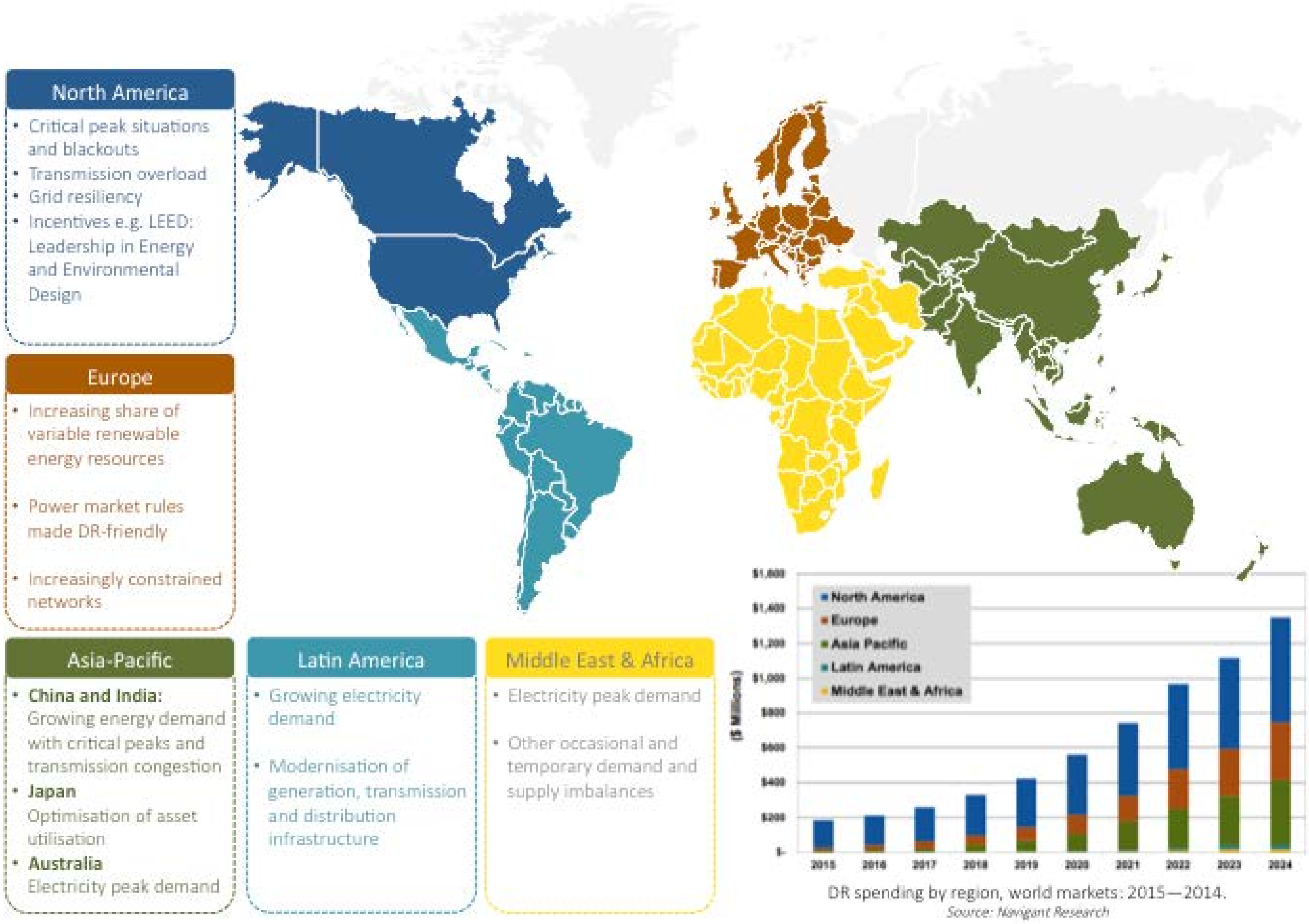

Figure 3: Projected evolution of demand response across the world. Source: Navigant Research (Lower-right plot); CEN Analysis (Rest of the plot).

Europe.

2.1. Regional drivers

Globally, DR has been traditionally implemented to reduce peak demand. This need for peak-shaving DR will be sustained in the future because of increasing electricity demand that is driven by population growth, urbanisation, industrialisation in developing nations, and a general trend towards electrification of traditionally fuel-based energy uses (e.g. transportation, replacement of oil and gas boilers with heat pumps, and ubiquity of ICT). The challenge to meet rising demand is compounded by the risk of faster growth in peak demand relative to overall consumption (e.g. mid-morning and early evening charging peaks from electric vehicles, and winter peak load from heat pumps). Today, few countries have excess peak capacity, and growing demand may quickly exhaust any that exists, making DR a compelling imperative as a cost-effective means of matching electricity demand and supply. As one example, faced with a capacity problem, France developed DR as a solution to its peak load challenge—demand peaks grew twice as fast as energy consumption between 2000 and 2010—and, also, to promote wholesale power market liquidity.[16]

As already mentioned, DR will be increasingly relied upon for load-levelling and ancillary services for balancing variable generation from renewable resources. Furthermore, for most parts of the world, particularly in North America, Asia Pacific, Europe and to a lesser extent in Latin America, DR is one of the priorities for smart grid development. For example, in India, DR is being considered as part of Buildings-to-Grid integration initiatives.[17]

The effective transposition of EU Directives into Member States Regulation is a critical DR driver within the EU. In a recent publication, the European Commission Joint Research Center[18] categorise the Member States into three groups: (i) the laggards that are under pressure to take DR seriously (e.g. Portugal, Span and Italy, where the obligatory EU Directives have been transposed but are yet to become legally binding, (ii) the second movers (e.g., the Nordics, Netherlands) that are considering DR in retail markets only, whereby DR will be bundled to the traditional electricity provision such that DR provision will be by and large limited to traditional retailers or BRPs, and (iii) first movers (Belgium, France, Ireland and the UK) that have opened all power markets to DR and independent aggregators.

2.2. Demand response markets

Figure 3 shows that DR remains predominantly used for the provision of (peak) capacity reserves, often requiring the use of back-up generators, and for price-based and incentive-based (i.e. economic) programmes. DR is not yet commonplace in ancillary services markets—even if changes in electricity mix suggest an increasing need for such fast DR—and for energy trading.

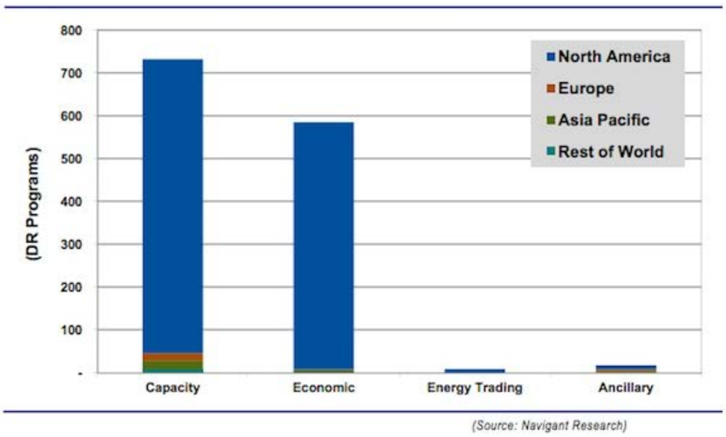

Figure 4: DR market types by region, World Markets 2Q 2013. Source: Navigant Research.

The increasing need for flexibility and risk management in power systems is likely to instigate a turnaround towards more balanced development of DR across different markets, if technical and regulatory challenges to implementing ancillary DR and market barriers to energy trading are addressed in a timely way.

2.3. Consumer segments

Most countries focus their DR development on commercial and industrial (C&I) consumer segments. There are however significant and untapped opportunities for residential DR. Two recent reports from Navigant Research estimate that the expected revenue from residential demand response and from C&I markets could, by 2023, respectively reach U.S. $2.3 billion[19] and U.S. $ 38 billion[20] worldwide (for an expected DR capacity of about 132 GW). Residential DR will grow as new technologies enable the provision of advanced DR programmes, e.g. non-disruptive direct load control (DLC) by service providers.

In effect, a 2015 study by SIA partners estimated that the DR potential from different processes and loads in different sectors could correspond in absolute terms to up to 9% of the peak load for 34 European countries. As shown in Figure 5, 42% of this potential would come from the residential sector, 31% from industry and 27% from the tertiary sector.[21]

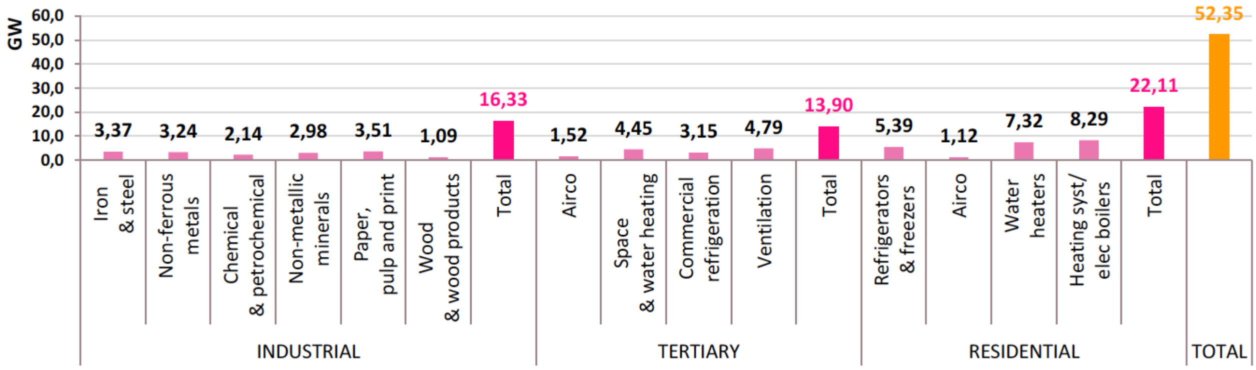

Figure 5: DR potential from different sources and sectors in Europe. Source: SIA Partners.

This said, residential DR is likely to grow at a slower pace than C&I DR, since barriers to adoption tend to be higher for residential DR (See Figure 3; Sections 3.3 and 3.4). Figure 6 shows that the extent to which residential DR is deployed or planned in Europe varies significantly across states. So do the mechanisms. In the Nordic countries, dynamic pricing is mandated and is the main driver of DR (see also Section 3.2, 3.3 and 4.2). Dynamic pricing is also envisaged in France as a next step of the French reform. Residential DR is stalled in Spain and Italy by a lack of dynamic pricing and consumer acceptance, respectively.[22]

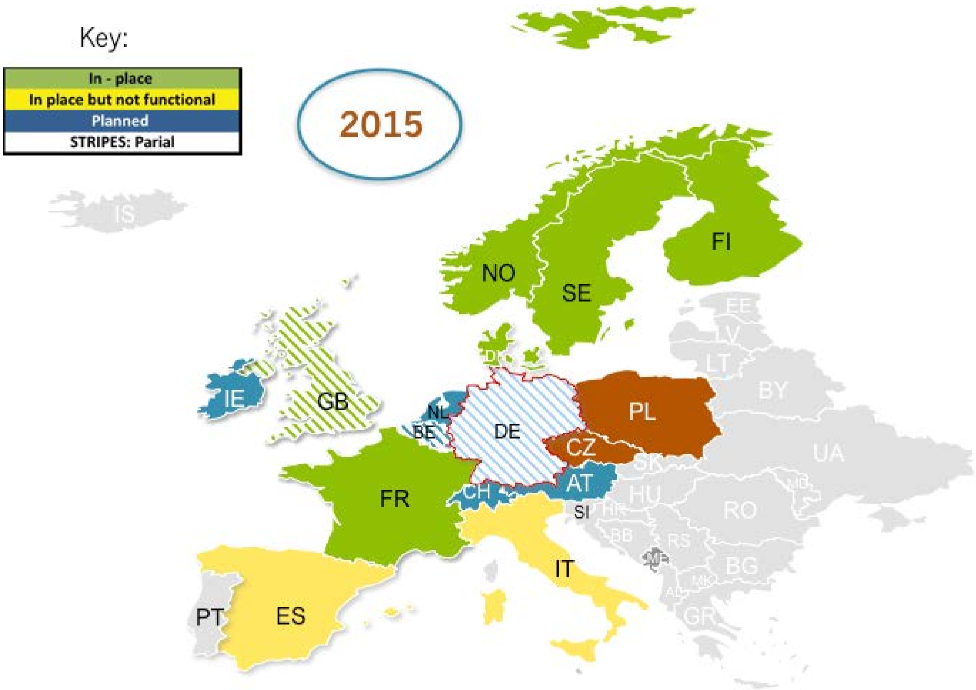

Figure 6: Residential demand response. Source: SEDC (2015).

3. BARRIERS

The key barriers to DR deployment can be summed up as uncertainties regarding the technical, economic and feasible potentials of DR. These correspond to, respectively, how much of DR can be provided by existing resources (encompassing physical assets, flexible operations and demand), to the financial viability of the technical potential, and how much of the economic potential can realistically be realised. Section 2 has highlighted some of the recent most evaluation of DR economic potential. We note that the uncertainty regarding these values is not shown. Furthermore, the feasible potential is stymied by lack of consumer engagement, inadequate investment in DR, high transaction costs, and opponents with vested interests.

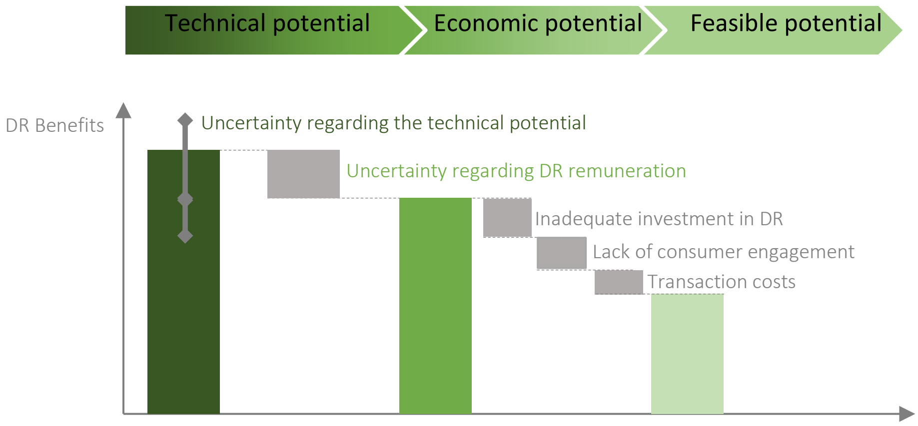

Figure 7: Conceptual illustration of the uncertainty regarding DR potential. Source: CEN Analysis.

Green bars indicate the magnitude of technical, economic and feasible potentials, and grey bars reductions in potential relative to the technical potential and the corresponding drivers. NB: The heights of green and grey bars are illustrative only and not based of any quantitative analysis.

3.1. Uncertain technical potential and impact

There is a lot of uncertainty regarding DR potential and impact due to the complexity of both power systems operations and advanced forms of DR. In particular, DR does not always translate into energy efficiency. This may create ambiguity regarding the desirability of DR. For instance, economically viable use of thermal loads from buildings for DR can lead to increase in comfort, but due to an increase in energy consumption. In this case, the increase in energy consumption is due to load-levelling DR that helps absorb excess renewables.[23] But there are instances, mostly in U.S., where high-emitting behind-the-meter generators, e.g. diesel generator sets, are used to respond to DR events. In general, the uncertainty regarding the feasible potential DR and ambiguity of impact from a systems perspective may limit its regulatory acceptance as a desirable power system resource, and should be addressed.

3.2. Uncertain economic potential

DR has an uncertain economic impact, since the latter depends on the type and volumes of DR, as well as regulatory choices concerning DR remuneration. In the United States, DR is remunerated at locational marginal price (LMP) as per the FERC Order 745, which stipulates equal compensation for a megawatt generated and a megawatt not consumed (i.e., a "negawatt"). While it is true that a negawatt substitutes for a megawatt, the rationale for equal compensation is flawed from an economic perspective. This is because a negawatt is never bought in the first place, and should therefore not be remunerated.[24] The reward for peak-shaving DR is lower electricity bill. In effect, DR does not even have to be remunerated in the presence of dynamic pricing. As a result, alternative forms of DR remuneration, particularly for peak shaving will emerge in other countries. Additional uncertainty comes technological developments, especially distributed storage, that may complement or substitute for DR.

3.3. Uncertain consumer engagement

The long-term behavioural impact of DR together with other emerging technologies is not yet fully understood. Consumer fatigue or satisficing behaviour may become an issue with price-based and incentive-based DR, unless DR is automated. Even then, consumers may be reluctant to relinquish control of their energy use to utilities or service providers. In this frame, Opower[25] suggests that residential consumers should be engaged incrementally, raising the levels of DR sophistication step-wise, to ensure widespread DR acceptance, particularly of advanced forms of DR such as DLC, which holds the promise of higher system benefits. Technology is not an issue; what is needed is more consumer centricity, because unless automated DR is implemented, consumer engagement may wane over time.

3.4. Inadequate utilities' investment

Utilities have traditionally worked towards reducing OPEX and increasing return on capital invested, since regulation has traditionally incentivised capital investment. With DR, operations will become more complex, requiring innovative front- and back-office customer operations to engage with customers and provide reliable services. Accordingly, OPEX will increase, both in absolute terms and relative to CAPEX. DR requires an adaptive shift from CAPEX to OPEX mind set on the part of utilities.

In addition, advanced forms of DR will operate on a common infrastructure, as captured by concepts such as GWAC's "transactive energy" and Navigant's "energy cloud." An element that is often missed is the heavy investment in ICT platforms that is needed to make these happen. And, since these technologies have a public-good characteristic (i.e., provide benefits even to those who do not invest in the technology), no individual stakeholder will invest into or contribute to it unless appropriately rewarded. This is exacerbated by the fact that although power system flexibility will require a portfolio of resources, the long-term contribution of DR is as yet uncertain. Unless DR generates revenues—to traditional utilities—that can be reinvested in advanced forms of DR, it is unlikely that DR will be developed in a timely way.

3.5. High transaction costs

The total transaction costs borne by DR participants and DR service providers are currently too high for DR to be economically viable or even feasible. Transaction costs borne by DR participants include the opportunity costs associated with education, qualification costs pertaining to telemetry and other equipment installation, energy audits, load monitoring, and other opportunity costs to the participant. Transaction costs to DR service providers include personnel costs associated with time spent on activities such as filling out a DR programme application, designing DR offers, and managing DR events. DR might thus fail to benefit residential consumers due to stringent qualification rules. Moreover, high transaction costs mean that aggregators favour large consumers, and marginal economic opportunities will be left out, even if technically they can contribute to overall DR capacity. As a result, it is difficult to capture the full potential of DR.

3.6. Opponents with vested interests

Many incumbent utilities still try to oppose the development of DR, despite the realisation that DR can cost-effectively address the challenges of increasing shares of renewables as well as new consumption peaks due to electrification.[26] This particularly applies to utilities who own peak and flexible generating plants and who therefore view DR as a threat to their traditional business. Because of their incumbency, they have strong lobbying power on the regulatory front, which they may exploit to ensure that regulation does not move fast enough or in favour of DR that is provided by new players. For instance, regulation may provide longer contracts to traditional peak and flexible generators than to DR providers. Or, it may set minimum capacity requirements for market participation too high, foreclosing market to DR aggregators.

4. RECOMMENDATIONS: REGULATORY AND MARKET LEVERS

The overarching challenge for policy makers and key market players will be to redesign the power market to bolster the competitive development of DR. The difficulty for restructuring power markets should not be underestimated, since power markets need to simultaneously embed flexibility on the demand side and sufficient capacity on the supply side by synergistically combining a range of resources, which differ in their flexibility attributes. It involves redefining roles and responsibilities of incumbent players and new entrants in an evolving market, establishing appropriate pricing at different levels, lifting market-entry barriers to allow for broad-based market participation and for developing competition in retail markets, and establishing an appropriate risk-management framework.

4.1. Redefining roles and responsibilities

A number of recent studies[27,28,29] have highlighted the need to adapt the roles and responsibilities for Transmission System Operators (TSOs), Distribution System Operators (DSOs), Balance Responsible Parties (BRPs) in view of power system decarbonisation. In doing so, an integrated approach needs to be taken in view of the evolution of power systems, where consumers are turning into more active participants by taking on roles of prosumers or engaging in DR, and incumbents are losing revenues to new entrants (e.g. DR aggregators). In effect, the bulk of innovation in the DR landscape originates from aggregators (e.g. Comverge[30] and EnerNOC, both with established operations in the Americas, and an expanding global footprint), and other service providers that specialise in energy management systems, e.g. Honeywell, Schneider Electric, Eaton and Siemens, all of which operate internationally. The rise of these contenders in the electricity market is often perceived as a threat to incumbent, local utilities.

Against this background, specifying framework conditions within which DSOs can safely evolve their operations and establish new strategic positions would limit defensive strategies on their part and foster more collaborative approaches, including strategic partnerships with energy service and ICT-service providers. A key element of such a framework design could be to foster DSOs' role of coordinating the exchange of flows, both data and cash, to ensure the timely exchange of the right type and quality of information between partners to trigger a DR event. New responsibilities for DSOs could also include working together with TSOs for cross-border intelligent resource balancing, including DR. This involves a shift from competition to coordination with TSOs, effectively creating a TSO-DSO interface[31] to provide, in the case of Europe, a pan-European balancing mechanism.

Establishing appropriate framework conditions also include adapting the terms for balancing the system—a role taken by Balance Responsible Parties (BRPs)—to the new realities of power markets. The effectiveness of BRPs in helping with variable generation and DR can be enhanced by allowing them to participate in short-term, intraday markets using all possible resources (generation, storage and DR) in a market-based way. To the extent that this is not the case, TSOs should grant BRPs the possibility to balance their position up to real time in a technologically neutral way. Furthermore, to encourage the development of a variety of and reliable DR resources, the balance responsibility and costs should be borne by those generators that cause imbalances, including wind and solar, as long as the costs are not prohibitively high.[32]

Going forward, incentives have to be designed in such a way that utilities deliver a minimum performance level, and still be able to choose to provide other value-adding services. New regulation for extending the role of utilities are being developed in the U.S., e.g. as part of New

York's REV (Reforming the Energy Vision).[33] This is particularly important since a common infrastructure of platform is needed to capture the full value that DR can provide to the power system. Incentives influence the development of valuable ownership structures for these platforms, through the distribution of DR value that is captured. It is equally important to ensure that liquidity in intraday markets and risk premiums for imbalance settlement are preserved, e.g. by allowing a sufficiently diverse set of players and resources to participate in the market.

4.2. Enabling dynamic and transparent pricing

The integration of an array of demand-side flexibility resources adds complexity to pricing, the design of which is critical because of the price sensitivity of investment, business models and behaviour of market participants. To be effective, prices should reflect generation and network constraints and evaluate the benefits that additional resources bring to the system.

An important first step in pricing design is the removal of retail price regulation to foster DR at the retail level as in the case of the Nordic countries. In most countries, retail prices are regulated to protect small consumers from price volatility and excessively high prices. The downside is a lack of pricing signals to consumers, especially at the residential level. In the present context, price deregulation together with DR can bolster competition in retail markets and may help mitigate price volatility. Furthermore, properly implemented, price deregulation enables the extraction of value from smart metering by allowing for smarter pricing and smarter contract offerings to consumers. For instance, consumers can choose, from a menu of contracts, different service levels and correspondingly prices, according to their reliability needs and risk preferences. Price deregulation thus encourages the development of new contractual mechanisms that ensure that costs are allocated to customers who value and are willing to pay for more reliable and cost-effective energy services.[34] In this way, new power system dynamics vitiates the very *raison d'être* of regulated prices.

Electricity should increasingly be priced at the locational marginal price (LMP). This is already the case for the wholesale electricity prices in the US. For distributed resources to provide DR, the distribution/retail rates must also be set such that they reflect the reliability benefits of their deployment. Distributed locational marginal prices are one option[35] that also confer the advantage of facilitating the balanced treatment of distributed resources into planning decisions and cost allocation. LMP has the additional merit of providing regional pricing signals, which are important to allow for cross-border flows and market integration to build greater flexibility into the system.

The next important step is to ensure efficient price discovery for DR. Auctions provide an efficient price discovery mechanism and some countries are already experimenting with them. The UK, for example, has set up the Transitional Arrangement (TA) auction as a special DR-only auction to bolster the integration of DR in UK capacity markets.[36] This boosts the value of assets dedicated for other DR end-uses such as short-term operating reserves (STOR) and frequency response by allowing these assets to tap into multiple value streams. To ensure efficiency of market outcomes in such settings, multi-part bids—as implemented in Poland and Germany—have been shown to improve the flexibility of short-term power markets.[37]

4.3. Lifting market-entry barriers

DR must be able to compete on fair grounds with supply-side resources in all power markets to unleash its full potential. Similarly, all resources that are eligible for providing DR should be able to bid into the market. This is particularly important in view of the growth of distributed generation and (eventually) storage, as well as smart metering.

To facilitate participation, especially of retail consumers, the qualification requirements for DR programmes need to be relaxed. The current procedures often involve tedious performance measurement and verification protocols that raise the transaction costs associated with DR. Moreover, telemetry requirements and minimum bid thresholds pre-empt the participation of a number of DR resources, particularly from the residential sector. By streamlining the eligibility criteria and approval processes, policy can help reduce transaction costs, effectively turning DR into an earnable asset for a broader stakeholder base.

To ensure the participation of a broader range of loads, especially small ones, policy makers should ensure market entry barriers for DR aggregators are effectively lifted. On the one hand, aggregators should be allowed to bid as a single consumer. On the other hand, unbundling should be made stricter. Otherwise, market entry may effectively be deterred: as new players, aggregators incur significant transactions costs for consumer acquisition, and run a risk of losing their business to incumbent utilities, which, in the absence of unbundling, have visibility over the aggregators' efforts yielding them an unfair competitive advantage. For instance, in Europe, there are about 2500 DSOs (~700 in Switzerland and ~800 in Germany) but only utilities with over 100,000 customers are strictly unbundled. At present more than 80% of these utilities serve less than 100,000 customers—and therefore exempt from any functional unbundling requirement.

Additionally, markets may need to be opened sequentially to accommodate new DR players and resources depending on the current context, encompassing the technical potential of DR, the extent of market liberalisation, and degree of market power within each power market. This policy of sequential opening of markets was implemented in the case of the French market redesign and is particularly important for resources such as electric vehicles and heat pumps due to their contemporaneously low market share. Too rapid integration of new resources and/or market players may distort incentives, especially in view of the fact that the structure of the markets and emergent business models are very intertwined, and can adversely affect social welfare via price effects and/or ex-post market foreclosure.

4.4. Harmonising energy policies

Utilities' incentive for providing DR depends on the regulation in place. DR requires intelligence solutions that increase operating expenses (OPEX) while some regulation, particularly cost-plus regulation tend to promote capital-intensive investment. In Europe only, different regulatory models (cost-plus regulation, cost of service regulation, performance-based or incentive-based regulation, price-cap and rate-of-return regulation) have been adopted, with some countries using a combination of models.[38] Depending on the regulation currently in place, it may need to be revised to ensure that DR develops as a viable power system resource.

In parallel, establishing a level playing field among different resources by revisiting the incentives in the energy system should be a priority. And, since the optimal operation of power system would require a mix of resources, integrated perspectives must be taken to align the incentives for different resources. For instance, DR will fail to take off in many countries in the absence of political mandates unless distortionary incentives such as subsidies (a form of negative carbon price) to coal power plants are removed. The co-existence of coal subsidies and feed-in-tariffs exacerbates distortions in power markets and makes it difficult to properly account for the potential contribution of DR.

Last but not least, we note that European Directives such as Art 15.8 of the Energy Efficiency Directive (2012/27/EU) tend to be very general, and are not binding unless and until implemented in national laws. To ensure swift yet coordinated DR implementation, European policy makers should move forward with the establishment of so-called Network Codes for DR. Network codes are a set of rules that govern the actions of technology suppliers and grid operators and determine how access is given to users. They have the advantage of being immediately applicable and provide regulatory certainty. DR falls under the umbrella of the Network Code for Electricity Balancing (NCEB), but further refinements are needed to the NCEB to bolster DR.[39]

4.5. Adopting a risk management approach

The many uncertainties regarding DR potential, trade-offs and risks involved may prevent its timely development. The following three steps could help better manage risks associated with DR development and deployment:

Step 1: Establish and promote the use of standardised and independent ex-ante protocols and tools to evaluate the technical potential for DR. Robust estimates of DR potential are necessary to help design appropriate policies and regulation, prioritise investments, and make other strategic decisions. In particular, standardised tools will reduce the risk for small and medium-sized projects.

Step 2a: Assess the technical risks associated with DR projects upfront, ensuring that they are well communicated between DR service providers, investors and/or participants.

Step 2b: Identify and address the obstacles to a cost-effective deployment of DR.

Step 3: Address residual risks via contractual risk transfer mechanisms such as insurance against business interruption risks, particularly relevant in the case of C&I DR, or asset performance risks.

These steps will increase participants' confidence in DR projects' and protect them against potential downsides, and should accordingly encourage DR uptake from bottom-up.

4.6. Summary of recommendations

Recommendations	Specific objectives	Barriers addressed
Redefining roles & responsibilities	• Specify clear framework conditions for incumbent utilities to leverage their role • Assign balancing responsibilities on the causer's principle	• Incumbents' opposition to DR due to uncertainty regarding business continuity in an evolving market • Increasing reliability costs due to renewables • Slow development of DR
Enabling dynamic & transparent pricing	• Deregulate prices, allowing dynamic pricing at retail level • Establish locational marginal pricing at all levels • Implement auctions for efficient price discovery	• Lack of consumer engagement due to lack of visibility on grid state • Uncertainty over economic potential of DR
Lifting market-entry barriers	• Create a level playing field for all actors and resources that are eligible for DR • Streamline procedures for DR participation • Reduce transaction costs	• Differential treatment of flexibility of conventional plants and demand-side resources • High qualifications costs, foreclosing the market to valuable, small DR loads from residential segment
Harmonising energy policies	• Adapt utilities regulation to foster a balance between utilities' capital and operation investment • Remove distortionary subsidies to coal • Make provision for DR in Network Codes (EU)	• Incumbents' opposition to strategic delay to firmly engage in DR • Political delay in institutionalising DR at national levels
Establishing a risk management framework	• Establish and promote use of standardised tools to evaluate DR potential • Address risks and obstacles to DR delivery upfront • Design risk-transfer mechanisms for residual risks	• Uncertainty regarding technical, economic and feasible potential • Uncertainty regarding technical, economic and feasible potential

5. CONCLUSION

The societal value of DR is increasingly recognised by many institutions, which also claim that DR is needed for energy transitions. However, the pace at which DR is being deployed remains slow. The future of power systems is open; the landscape will be defined by prosumers and other actors competing to provide an array of flexibility services. There is a window of opportunity to influence the future of power systems and to leverage the system value of DR.

Going forward, it is firstly important to put in place a holistic approach and a unifying framework for assessing the added value of DR to future power systems. The emerging power system can be best seen as a hybrid system that brings together all loads, generation sources and storage capability in a synergistic way, albeit at the cost of increasing power system complexity.

Secondly, value extraction from this mix of heterogeneous resources hinges around sound market redesign that takes into account the physics of power generation and distribution, but also the innovative ownership schemes that seek to change the modus operandi of power systems. When considering power system reforms and investment needs, it is imperative to avoid the pitfall of myopia and consider that:

a) Technologies are evolving that would leverage the potential of DR across a broad range of resources from buildings energy management to electric vehicle storage. Uncertainties regarding the evolution of the technologies and associated DR capacity should be handled appropriately in power system planning.
b) Markets are opening up that facilitate the participation of a broader range of actors. In Europe, for example, market coupling opens up the geographical scope of DR from national to a pan-European level. This contraction in space is not only a market design issue but also a network investment issue.
c) Increased frequency and severity of extreme events related to climate change increase the exposure of power systems to supply disruptions. DR can contribute towards increasing the resilience of power systems.

Thirdly, it is quintessential to strive for a judicious combination of market mechanism and regulation to foster DR. Market-only solutions are often not sufficient in view of the presence of market failures such as transaction costs. For example, in California (one of the leaders of DR in the U.S. and globally), DR growth was fuelled by a number of events and generous political support. The latter has subsided thereafter. Evidence from U.S. and some parts of Europe indicate that government support for DR is instrumental for DR to take off. But, over-reliance on regulation and policy means that effective development of DR can be stalled as political priorities shift. A regime that combines the strengths of market-oriented and regulatory initiatives seems to be more appropriate, especially in the early stages of development and deployment, during which some incumbent players will be destabilised and may need to be compensated.

Future power systems will be open, modular, diversified and with sufficient redundancy for enhanced resilience. In such systems, each resource is represented as a node in the system that can be switched on or off depending on the state of the grid and subject to the constraints of the laws of physics. In it, DR is perhaps the lowest hanging fruit that acts as a linchpin both during and after power system transformation.

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GLOSSARY

Balance Response Party (BRP) A 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.

DR 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 rewards from utility operators for doing so and reward end-users for the provision of demand flexibility.

Energy Cloud is a term used by Navigant to describe the emerging two-way connected digitized grid, with more distributed and variable energy resources, highlighting the changing power system landscape from a one-way system from generation to distribution. (https://www.navigantresearch.com/research/the-energy-cloud)

Power market liquidity is an important indicator of the effectiveness of wholesale electricity market competition. A liquid market is characterised by the presence of a large number of buyers and sellers that transact at all times and in which no single transaction can cause major changes in prices. (https://www.ofgem.gov.uk/electricity/wholesale-market/liquidity)

Power system flexibility expresses the extent to which a power system can smooth out fluctuations in electricity demand and production, including but not limited to increasing/decreasing electricity production or consumption in response to variability, expected or other otherwise (i.e., under uncertainty).

Transactive Energy is a concept introduced by GridWise Architecture Council to denote "techniques for managing the generation, consumption or flow of electric power within an electric power system through the use of economic or market-based constructs while considering grid reliability constraints," considering the fact that decision-making is based on some value preferences. (http://www.gridwiseac.org/about/transactive_energy.aspx)

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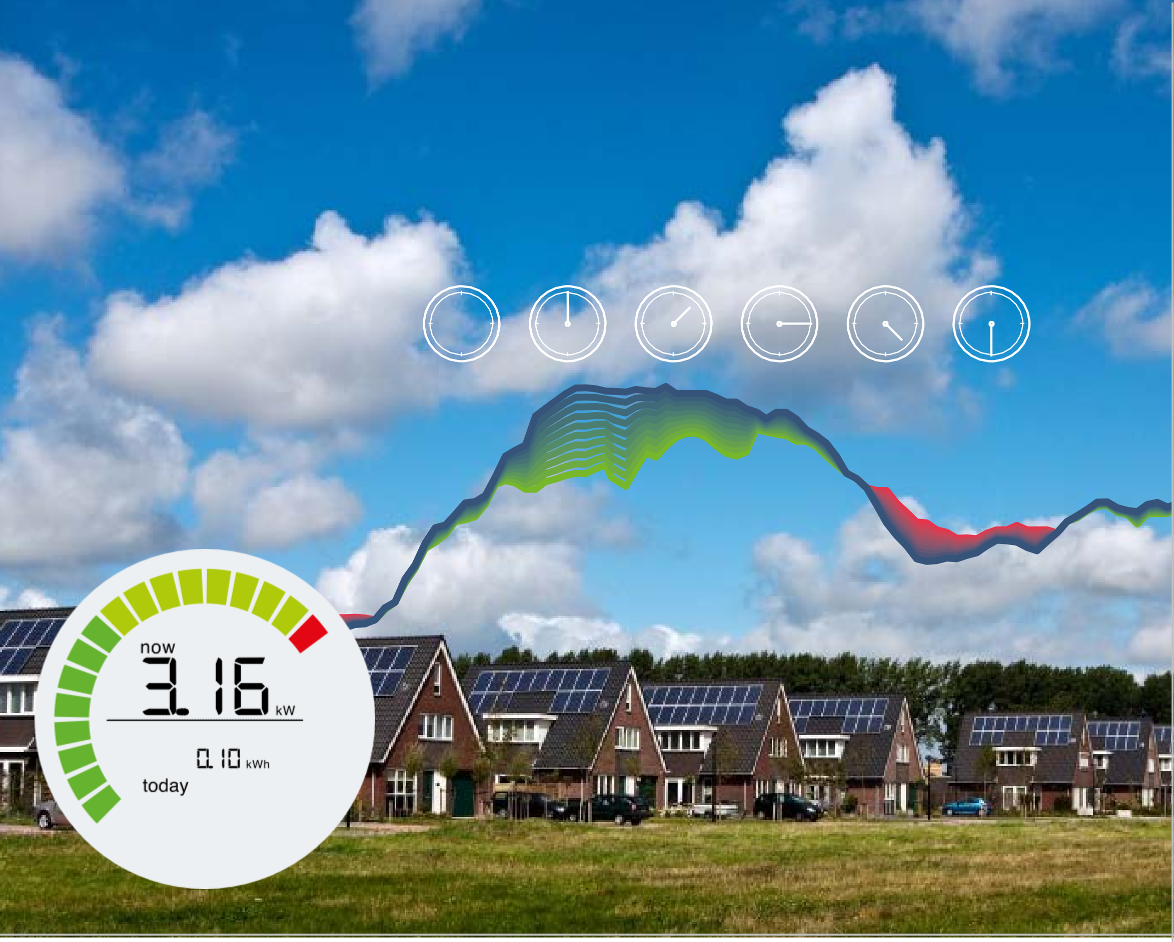

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