IRENA
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# REDESIGNING CAPACITY MARKETS

## INNOVATION LANDSCAPE BRIEF

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## About IRENA

The International Renewable Energy Agency (IRENA) is an intergovernmental organisation that supports countries in their transition to a sustainable energy future, and serves as the principal platform for international co-operation, a centre of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy. IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity. **www.irena.org**

## Acknowledgements

This report was prepared by the Innovation team at IRENA's Innovation and Technology Centre (IITC) and was authored by Arina Anisie, Elena Ocenic and Francisco Boshell, with additional contributions and support by Harsh Kanani and Shikhin Mehrotra (KPMG India).

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## Disclaimer

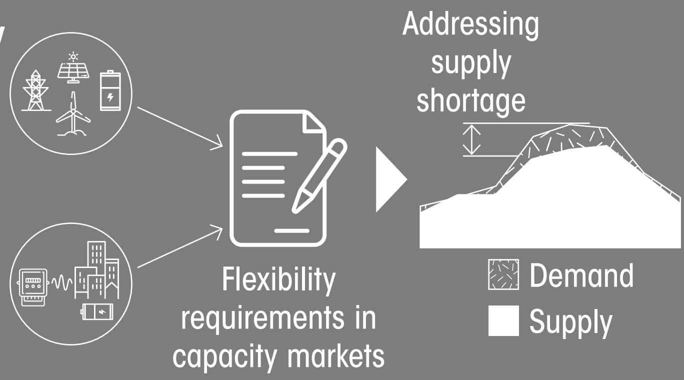
## 1 KEY INNOVATIONS IN CAPACITY MARKETS

Introducing flexibility requirements to ensure new flexible capacity additions

Allowing new participants in the market, such as storage, interconnections, demand response and VRE resources

**Supply-side capacity resource:**
- VRE resources
- Battery storage
- Interconnectors

**Demand-side capacity resources:**
- Demand response




## 3 SNAPSHOT

- Under the French capacity mechanism, consumers with flexible loads can opt to provide **demand response**.
- In Alberta, Canada, the capacity markets require all participants to submit **the ramping capability**.
- In the single electricity market of Ireland and United Kingdom, **interconnectors, renewable energy sources and demand response are allowed** to participate in capacity markets.

## 2 KEY ENABLING FACTORS

- Adoption of a clear methodology for defining the capacity credit of VRE resources
- Deployment advanced metering infrastructure for demand-side participation

## WHAT ARE CAPACITY MARKETS?

Power systems need a mechanism to ensure **generation adequacy** and **security of supply**. Capacity markets serve this purpose.

# REDESIGNING CAPACITY MARKETS

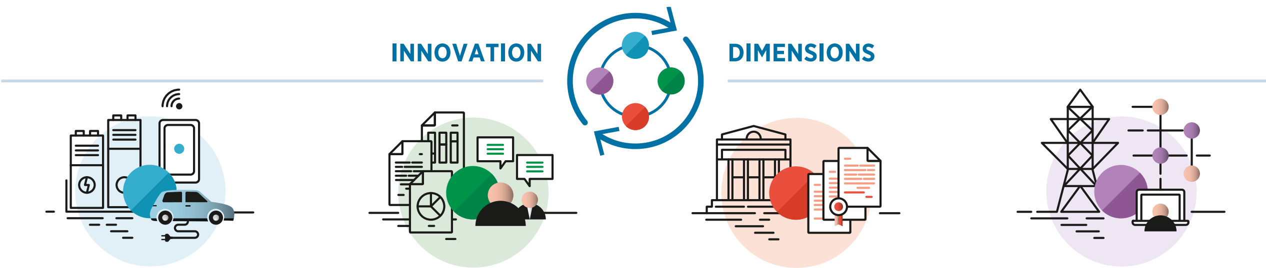
Redesigning capacity markets **fosters flexibility**, allows entry by **new participants** and enables the integration of **high shares of VRE**.

# ABOUT THIS BRIEF

This brief forms part of the IRENA project "Innovation landscape for a renewable-powered future", which maps the relevant innovations, identifies the synergies and formulates solutions for integrating high shares of variable renewable energy (VRE) into power systems.

The synthesis report, *Innovation landscape for a renewable-powered future: Solutions to integrate variable renewables* (IRENA, 2019), illustrates the need for synergies between different innovations to create actual flexibility solutions for power systems. Solutions to drive the uptake of solar and wind power span four broad dimensions of innovation: enabling technologies, business models, market design and system operation.

Along with the synthesis report, the project includes a series of innovation landscape briefs, each covering one of 30 key innovations identified across those four dimensions. The 30 innovations are listed in the figure below.




**ENABLING TECHNOLOGIES**

1 Utility-scale batteries
2 Behind-the-meter batteries

3 Electric-vehicle smart charging
4 Renewable power-to-heat
5 Renewable power-to-hydrogen

6 Internet of things
7 Artificial intelligence and big data
8 Blockchain

9 Renewable mini-grids
10 Supergrids

11 Flexibility in conventional power plants

**BUSINESS MODELS**

12 Aggregators
13 Peer-to-peer electricity trading
14 Energy-as-a-service

15 Community-ownership models
16 Pay-as-you-go models

**MARKET DESIGN**

17 Increasing time granularity in electricity markets
18 Increasing space granularity in electricity markets
19 Innovative ancillary services
20 Re-designing capacity markets
21 Regional markets

22 Time-of-use tariffs
23 Market integration of distributed energy resources
24 Net billing schemes

**SYSTEM OPERATION**

25 Future role of distribution system operators
26 Co-operation between transmission and distribution system operators

27 Advanced forecasting of variable renewable power generation
28 Innovative operation of pumped hydropower storage

29 Virtual power lines
30 Dynamic line rating

This innovation landscape brief provides an overview of innovations in capacity market design features that ensure that the generating resources are adequate to meet demand at all times. Capacity markets are not, in themselves, an innovation. Their comprehensive redesign, however, allows the necessary flexibility for the future system to integrate high shares of solar and wind power. This brief introduces innovations in capacity market requirements, together with new actors that should be allowed to participate in the markets.

The brief is structured as follows:



# I. DESCRIPTION

With increasing installation of renewable generation capacity, in particular wind and solar photovoltaic (PV), power systems require large amounts of flexible resources to provide quick responses to mitigate the additional variability and uncertainty created by the generation of variable renewable energy (VRE). At times, electricity markets prove to be insufficient to compensate flexible resources for their services. Ancillary service markets may cover some of these costs, but in some cases, they cannot attract enough additional investment in flexible resources in the longer term.

Moreover, prices in electricity markets are sometimes considered by market participants to be inadequate to meet medium-term to long-term resource investment needs. The high penetration of VRE displaces conventional baseload generation and depresses prices in the short-term markets (even to negative price levels) due to their zero marginal costs. Renewable energy technologies have decreased the load factors of many conventional baseload plants, which are increasingly used to provide flexible generation when VRE is not available.

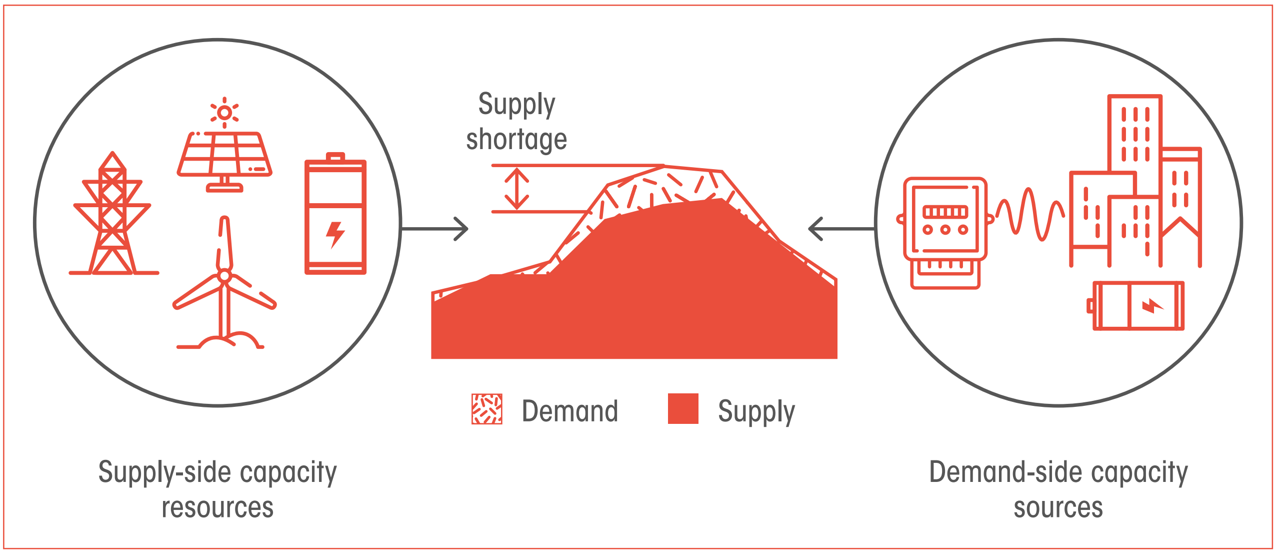
Capacity markets can co-exist alongside the energy-only (electricity) and the ancillary service markets. They are a mechanism to ensure the adequate medium-term and long-term security of supply by remunerating generators for the availability of their resources. The aim is to fill the expected capacity gap in the presence of volatile and unpredictable renewable generation plants. By focusing on the long-term security of supply issues, capacity markets incentivise investments into adequate generation capacity.

While low wholesale electricity prices are good for end-consumers, low prices (even negative prices) hamper medium-term and long-term investments in new generation capacity. To ensure resource adequacy and reliability of supply, several countries and regions have introduced, in addition to the electricity markets, schemes to remunerate market participants for their available capacity via capacity markets. Adding a capacity market in addition to an electricity market is useful in cases in which a resource adequacy issue has been identified.

Under capacity mechanisms, capacity prices are either set in advance administratively or are the result of market-based principles (for example, auctions) and are independent of the cost of the energy produced. Such capacity prices are based on the cost of providing the required capacity whenever needed. These capacity payments are often designed for long periods of time. For example, in the United Kingdom, the capacity market agreement for new generators is 15 years, which incentivises market participants to invest in capacity with a long-term security of supply perspective.

Originally, capacity markets were designed for conventional generation power plants, which have a firm and controllable power output. However, in future power systems that are characterised by a high share of VRE, flexibility is crucial and could be incentivised via capacity mechanisms. Additionally, allowing consumers to adjust their consumption based on price signals would increase demand-side flexibility in the system by shifting consumer demand from peak to off-peak periods. Similarly, other new market participants should be allowed to participate in a capacity adequacy mechanism, based on their firm capacity. Together with demand response, other flexible capacities – such as battery storage technology (when exporting energy to the grid) and interconnections – could contribute to the reliability of the system in times of shortage of su1pply. This is depicted in Figure 1.

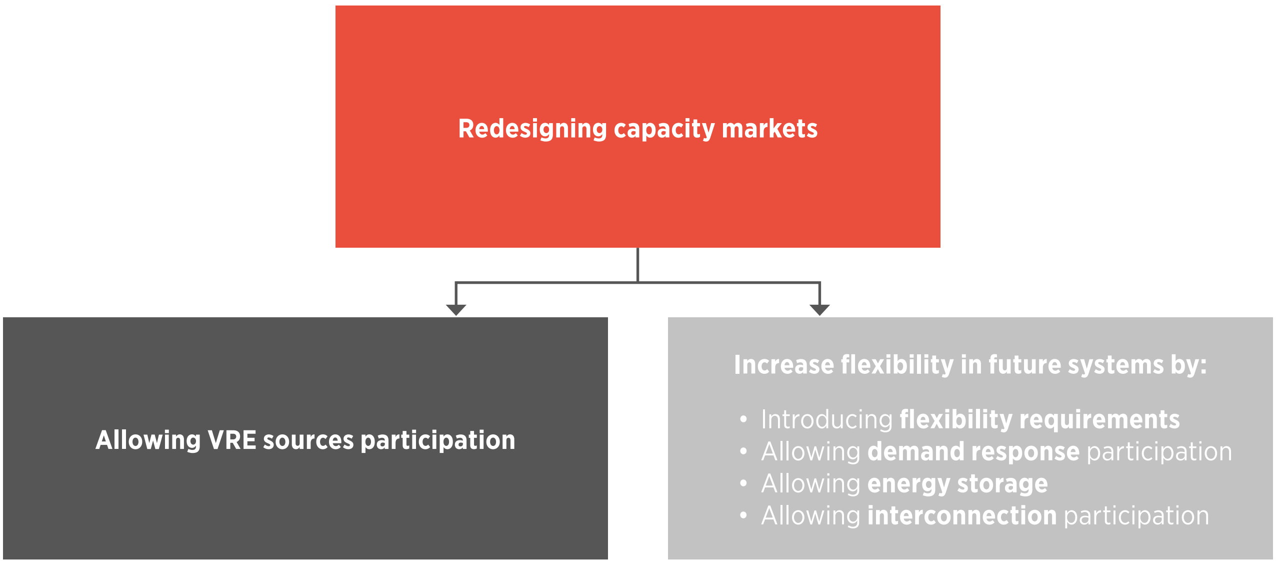
**Figure 1:** New participants in capacity markets addressing supply shortages



# II. CONTRIBUTION TO POWER SECTOR TRANSFORMATION

Introducing flexibility requirements in capacity markets, such as ramping requirements, improves the integration of VRE into the power system. Similarly, allowing new participants in capacity markets, such as energy storage, demand response and cross-border participation (through grid interconnectors), contributes to cost-effective system expansion and a flexible system. Moreover, VRE technologies should increasingly be encouraged or mandated to participate in all markets, including energy-only and capacity markets, and therefore be exposed to the same incentives as any other generation technologies. This would avoid distortions in the market.

**Figure 2:** Key innovations in capacity markets for a renewable energy-based, flexible system



## Incentivising VRE deployment by allowing VRE resources to participate in capacity markets

Conventional power plants have been the main participants in capacity markets due to the predictable and controllable nature of their power output. In some cases, VRE resources, such as wind and solar energy, have also helped to ensure resource adequacy. Generally, however, the contribution of VRE resources to the security of supply is lower per unit of installed capacity than for conventional technologies. Their contribution depends in part on the specific conditions of the power system, such as its location and scarcity conditions (whether it is a capacity-constrained or an energy-constrained system). Yet the integration of VRE into the system is increased by allowing these resources to play a role in capacity markets, with providers being remunerated for their services (IRENA, 2017).

Several countries already have frameworks in place that allow VRE resources to participate in capacity mechanisms. For example, in France, electricity suppliers are required by law to procure capacity guarantees based on consumers' load patterns during peak periods in winter (1 November-31 March). Such capacity adequacy can be provided by thermal generators, renewable energy resources (RES) or demand response if the providers register and obtain the necessary certification. Such certificates of guarantee are then traded in the capacity market (RTE, 2015).

In the United States, the Pennsylvania-Jersey-Maryland (PJM) Interconnection, a regional transmission organisation (RTO), cleared 116 megawatt (MW) solar power plants and 803 MW wind power plants to provide capacity in 2017 and 2018 (FERC, 2015). (See Section IV.)

The European Commission has approved a new capacity mechanism for the single energy market in Ireland and the United Kingdom of Great Britain and Northern Ireland under which RES and demand response can participate alongside conventional generators (European Commission, 2017). A similar mechanism is being proposed in Italy and is awaiting approval from the European Commission (Bonucci, 2018).

## Means to increase flexibility in power systems

### *Introducing flexibility requirement in capacity markets*

The role of capacity markets has traditionally been to incentivise investments in new generation capacity. With the increasing penetration of VRE, an efficient means to increase flexibility in power systems is to introduce flexible resource requirements into the existing capacity mechanisms that could incentivise investments in more flexible resources, meaning resources that can ramp up and down quickly.

For example, in January 2017 the government of Alberta (Canada) launched the design and implementation of a capacity market in collaboration with the Alberta Electric System Operator (AESO). The capacity market requires all participating assets to submit the ramp capability. The first auction is planned in 2019 with the first delivery in 2021 (AESO, 2018).

### *Participation of demand-side response in capacity markets*

Demand-side response refers to the ability to reduce energy loads during times of supply scarcity. Under demand response, consumers are incentivised through price signals to reduce their consumption at times of supply deficit. Commercial and industrial consumers account for a large share of the peak demand and can change their consumption patterns with more ease than residential consumers. Demand response has proven to be competitive in the forward capacity markets operated by PJM and the independent system operator (ISO) for the New England region of the United States.

The capacity value of aggregated distributed energy resources (DERs) can also be used to satisfy long-term resource adequacy requirements or to defer other infrastructure investments. Some capacity markets, such as Alberta's capacity market, allow the participation of aggregated DERs, which is further explained in Section IV. Similarly, under the French capacity mechanism, consumers with flexible loads can opt to provide demand response either to electricity suppliers during winter peak times or to system operators whenever needed (RTE, 2015).

PJM introduced the US "reliability pricing model" (RPM) under which demand response resources are treated like generation resources, ensuring the security of supply. Demand response resources are paid to be "available" during expected emergency situations with monthly to yearly commitments (PJM, 2018a).

The Spanish transmission system operator (TSO) Red Eléctrica de España procures an "interruptibility service" in which large consumers reduce their demand through demand response when requested by the TSO. This service covers two capacity products of 5 MW and 40 MW, respectively, that are procured via auctions conducted by the Red Eléctrica de España (Red Eléctrica de España, 2018).

*Storage participation in capacity markets*

Energy storage resources also participate in capacity markets by committing to discharge energy when requested by system operators to ensure the security of supply. These resources are usually rewarded based on the duration of discharge they provide. They are a great source of flexibility for the system, and their participation in capacity markets provides them with an extra revenue stream, which in turn incentivises their further investments. Many markets already allow storage participation in capacity markets.

The UK's TSO, the National Grid, plans to procure about 50 GW of capacity in its forthcoming auctions for delivery in 2023. These auctions allow the participation of battery storage systems that provide at least 30 minutes of service. The de-rating factors for battery storage systems were changed in December 2017, making the revenues proportionately greater for systems with a longer duration of discharge (Colthorpe, 2018).

In the United States, the Federal Electricity Regulatory Commission (FERC) recently issued Order No. 841, which allows energy storage systems to participate in capacity markets. It also requires system operators to revise their tariffs and establish rules that recognise the physical and operational characteristics of energy storage systems (Walton, 2018).

*Cross-border participation in capacity market via interconnections*

Currently, the majority of capacity mechanisms have a national scope. Benefiting from available interconnections, regional capacity markets can play an important role in more efficiently co ordinating investment plans in generation capacity. Opening capacity market mechanisms to capacity providers in neighbouring countries or systems will incentivise investments in domestic and foreign capacity, as well as in interconnections, which will result in reduced system costs for all participating countries.

For example, in Great Britain, interconnectors, de-rated like batteries, have been allowed to participate in capacity market auctions since 2015. Interconnectors are treated like any other market participants such as generators or demand response and must deliver capacity when requested by system operators during stress events or pay penalties for under-delivery. The British model has witnessed participation from interconnectors with Belgium, Ireland and the Netherlands (Tennbakk *et al.*, 2016).

Similarly, in the single electricity market of Ireland and Northern Ireland, interconnectors have been allowed to participate in capacity markets alongside other energy resources such as renewable energy resources, conventional generators and demand response. No international capacity contracts have been witnessed until now (Tennbakk *et al.*, 2016).

# III. KEY FACTORS TO ENABLE DEPLOYMENT

## Adopting a clear methodology for defining the capacity credit of VRE resources

VRE resources produce a variable and an uncertain energy output. Therefore, the amount of reliable electricity that can be provided by VRE resources must be assessed based on a clear methodology.

For instance, in Colombia, the Colombian Energy Regulator (CREG) has established a metric called ENFICC (Energía Firme para el Cargo por Confiabilidad) that represents the maximum amount of power that a generator can offer as firm capacity in capacity market auctions. It is expressed as a percentage of the plant's total generation capacity (Robinson, Riascos and Harbord, 2012).

Such metrics can be established based on clear methodologies such as calculating the average generation during relevant shortage periods. Alternatively, a threshold percentile-based method may be adopted. For example, the level of wind generation that has occurred at least 85 % of the time (P85) may be considered as the firm energy contribution of wind power (Letson, 2015).

## Oversight and advanced metering infrastructure (AMI) for demand-side participation

Demand response and DERs can play an important role in providing flexible capacity reduction to ensure reliability in case of supply shortages. However, if aggregated DERs are relied upon for resource adequacy, the need to ensure that aggregators are genuinely capable of delivering capacity whenever and wherever needed becomes essential for reliability.

Developing the underlying infrastructure is key and includes smart meters, communication networks and data management systems, often referred to as "advanced metering infrastructure" (AMI).

## Regional mindset for interconnections participation in adequacy resource mechanism

Important savings can be realised when the security of supply is considered at the regional level, rather than at the individual system level, and when investments in interconnections are incentivised through capacity markets. The functioning of regional markets requires a high level of trust among countries that, in case of supply scarcity, they will share generation capacity according to the established rules rather than giving priority to local demand. This represents a major opportunity to reap benefits from regional integration, instead of installing local generation capacity to meet individual countries' demand (Perez-Arriaga, 2013).

# IV. CURRENT CONTEXT AND EXAMPLES OF LEADING INITIATIVES

## Alberta capacity market (Canada)

In January 2017, under the government of Alberta's direction, the AESO launched the design and implementation of an Alberta capacity market. This newly designed capacity market aims to achieve resource adequacy at least cost by facilitating broad competition among resources while working effectively and efficiently with the energy and ancillary service market. It also identifies the following assets that are eligible to prequalify: thermal, demand response, external capacity assets (through interconnections), storage, hydro, variable, and aggregated assets. In addition, it requires the minimum size of the assets to be 1 MW, whereas storage assets must demonstrate four hour continuous discharge capability to be able to participate in the market. Additionally, for all participating generating and storage assets, the ramp capability has to be submitted. In effect, this means the capacity market includes some flexibility requirements. The first capacity auction was scheduled for November 2019 with the first delivery of capacity in 2021 (AESO, 2018).

## PJM's reliability pricing model (United States)

PJM Interconnection administers a capacity market called the reliability pricing model (RPM) in the US market through which it procures capacity for reliability by including participation of both demand responsive loads and VRE resources. In its 2018 base residual auction, it cleared 116 MW of solar power capacity and 803 MW of wind power capacity (FERC, 2015). Furthermore, for providing demand response services, PJM compensates its end users for reducing their electricity usage upon PJM's request in the event of a supply shortage or threatened reliability of the grid (PJM, 2018b).

## French capacity mechanism

The French capacity market began in 2015, and a new demand response scheme within the capacity market was launched in February 2018. Under its new market design, capacity obligations are placed on electricity suppliers based on their customers' consumption profiles during the peak winter months. Both VRE and demand-side resources can participate in the capacity market. Each participating resource is certified for the amount of capacity it offers to suppliers upon request. Each participating resource obtains one certificate for every 0.1 MW of capacity offered in the capacity market. In addition, VRE resources are eligible to obtain historical certificates for the energy provided to system operators in situations of stress and during peaks prior to the introduction of the first capacity mechanism (RTE, 2015).

## Calls for the capacity market redesign in Great Britain

In Great Britain, the underlying reason to redesign the existing capacity market mechanism is to encourage investments and the deployment of flexible resources such as batteries. In February 2018, the capacity market auctions witnessed record low prices due to very high participation of the conventional generators, which were seeking additional revenue, while a very small amount of the more flexible battery storage was contracted. The capacity market forward auction for 2022 completed in February 2018 cleared at record low prices of ~USD (US dollar) 10.8/kWh (kilowatt-hour) compared to previous years' market clearing at ~USD 29/kWh.[1] Only 153 MW of battery storage capacity was contracted, even though significant capacity may have pre-qualified (Cuff, 2018).

However, the British capacity market has been on hold since November 2018 given the ruling of the General Court of the European Union that annulled the approval of the capacity mechanisms due to procedural reasons, such as the lack of a detailed formal investigation into the market design prior to its initial approval in 2014. One of the arguments against the design of this capacity market is that it discriminated against technology designed to cut electricity demand during peak times (European Commission, 2019).

1 Original figures of GBP (British pounds) 8.4/kWh and GBP 22.5/kWh converted to US dollars based on exchange rates prevailing on 21 August 2018 using quotes provided by Bloomberg (www.bloomberg.com/quote/GBPUSD:CUR).

# V. IMPLEMENTATION REQUIREMENTS: CHECKLIST

## TECHNICAL REQUIREMENTS

**Hardware:**

- Equipment, such as smart meters (required to provide real-time power consumption and production), home gateways (energy boxes), communication networks and smart appliances for energy management, are necessary for enabling the DERs' interaction with the existing grid
- Smart grids that enable two-way flow of data and electricity

**Software:**

- Automation of various processes and information exchange related to scheduling of power plants and demand response

## REGULATORY REQUIREMENTS

**Wholesale market:**

- Assess the need to establish or redesign capacity mechanisms based on the resource adequacy situation
- Define clear methodologies to calculate the amount of firm capacity that each resource can offer
- Introduce oversight regulation to ensure that new actors allowed to participate in capacity markets are delivering capacity when and where it is needed
- Incentivise the participation of VRE and storage, as well as interconnectors in capacity mechanisms, which can provide flexibility in addition to conventional generators

**Retail market:**

- Incentivise demand response, especially for commercial and industrial consumers

## STAKEHOLDER ROLES AND RESPONSIBILITIES

**Consumers:**

- Commit to respond to price signals and offer capacity when the system needs it in moments of scarce generation, *e.g.*, via automation, aggregators, etc.

**System operators:**

- Define capacity market products according to the flexibility needed in the system
- Conduct flexible capacity market auctions if a resource adequacy issue is identified
- Provide oversight and forecasts of system adequacy issues and the necessary capacity requirements, including potential shortages
- Update stakeholders about changes to the resource adequacy issues in the systems

## ABBREVIATIONS

| | |
|---|---|
| **AESO** | Alberta Electric System Operator |
| **AMI** | Advanced metering infrastructure |
| **CREG** | Colombian Energy Regulator |
| **DER** | Distributed energy resource |
| **ENFICC** | Energía Firme para el Cargo por Confiabilidad |
| **FERC** | Federal Electricity Regulatory Commission |
| **ISO** | Independent system operator |
| **kWh** | Kilowatt-hour |
| **MW** | Megawatt |
| **PJM** | Pennsylvania-Jersey-Maryland |
| **PV** | Photovoltaic |
| **RES** | Renewable energy resources |
| **RPM** | Reliability pricing model |
| **RTO** | Regional transmission organisation |
| **TSO** | Transmission system operator |
| **VRE** | Variable renewable energy |

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