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under the aspects of flexibility and technological progress

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Executive Summary

As concerns about generation adequacy are currently rising in Europe, decision makers try to incentivize investments in generating capacities and demand response measures. This document provides an up-to-date overview on currently implemented and proposed market design options in- and outside Europe.

Strategic reserves are currently used in Sweden (since 2003), Belgium (since 2014) and Poland (since 2016). Sweden is planning to phase-out thermal capacities and rely only on demand-response measures by 2020. If the offered prices in Belgium are regarded as clearly unreasonable by the Regulation Commission, a royal decree can impose prices and volumes. In Poland, the strategic reserve is planned to be replaced by a capacity market based on the UK model after 2020. Germany is introducing a strategic reserve in 2017.

Central buyer mechanisms are in place or planned in various European countries. The UK introduced its mechanism in 2014, however limited effects on demand response measures and new investments could be observed so far. Ireland is expected to introduce a central buyer mechanism in 2017, which will be replacing the current price-based mechanism. Multiple auctions with different time horizons will be used. Italy, currently using targeted capacity payments, is also planning to implement a central buyer mechanism in 2018. However, problems regarding compliance with EU law still have to be solved.

The only European country using de-central obligations is France, which plans to introduce the mechanism in 2017. All current technologies shall be allowed to participate with priority being granted to demand response measures. However, cross-border transmission flows are not directly eligible, but only considered in the calculation of the capacity to be certified.

Targeted capacity payments are used in Greece (current mechanism since 2016) and Spain (since 2007). Greece puts an explicit focus on adequate flexibility instead of considering only the available capacity. Spain differentiates between the availability service (medium-term focus) and the investment incentive (long-term focus). The investment incentive was abolished in 2016.

The analysis shows that different mechanisms have been implemented in several EU countries or will be introduced in the near future. However, as there is so far hardly any experience on the appropriate implementation of these mechanisms, they are subject to modifications and adjustments.

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1. INTRODUCTION

As concerns about adequacy of electricity supply are currently rising in Europe, decision makers try to support new investments in generating capacities and incentivize demand response measures. As this process is still ongoing and there exists a broad variety of options, the goal of this document is to provide an up-to-date overview on currently implemented or proposed market design options in European markets and other already established market designs outside of Europe. The selected markets can be grouped into different categories, but each still contains specific characteristics that can deliver further insights.

A market mechanism can be either targeted, e.g. applies only to selected technologies or new investments, or market-wide, i.e. all units are able to participate. Furthermore, one can distinguish between volume-based mechanisms, e.g. a certain capacity is required, or price-based mechanisms, where the procured capacity depends on the target price. The following table shows this classification of different capacity mechanisms as suggested by the European Commission (European Commission 2016):

	Targeted	**Market-wide**
Volume-based	Tender for new capacity	Central buyer
	Strategic reserve	De-central obligation
Price-based	Targeted capacity payment	Market-wide capacity payment

The basic principles of the different mechanisms are as follows (European Commission 2016):

- Tender for new capacity: The construction of new power plants is financed in order to establish the required top up capacity. Once the power plant is in operation, it can either run in the market as normal or be further supported through a power purchase agreement.
- Strategic reserve: The required top up capacity is contracted and held in reserve outside the market. The reserve capacity only runs when specific conditions are met, such as a shortage of capacity in the market or a certain maximum electricity price.
- Targeted capacity payment: A central body sets the price of capacity which is then paid to a subset of capacity operating in the market.
- Central buyer: The total amount of required capacity is set centrally and procured through a central bidding process, so that the market determines the price.
- De-central obligation: An obligation is placed on electricity suppliers to contract with capacity providers to secure the total capacity they need to meet their consumers' demand. In contrast to the central buyer model there is no central bidding process.

- Market-wide capacity payment: The price of capacity is set centrally, based on estimates of the level of capacity payment needed to bring forward sufficient total capacity and paid to all capacity providers in the market.

2. OVERVIEW

Objective	Administrator	Type of capacity mechanism	Capacity Agree-ment	Eligible techno-logies	Period	Description	What aspects are of special interest for the European discussion?	Sources
STRATEGIC RESERVE								
BELGIUM								
Back-up for demand peaks during the winter	Elia (TSO)/ Electricity and Gas Regulation Commission (CREG)/ Federal minister responsible for Energy	Strategic reserve	Agreements for 1–3 years	Conventional power plants that are in the process of closing/ mothballing (nuclear generation excluded)/ Demand side management	Started in 2014	• The required capacity for strategic reserved is calculated via a probabilistic market model, which takes into account neighboring countries, outages, demand thermosensitivity and needs to fulfill the following constraints: 1. Average LOLE < 3 hours 2. LOLE P95 < 20 hours • Availability requirement from 1st of November until the 31st of March • Capacity procured in competitive tendering procedure, but if offered prices are regarded as clearly unreasonable by CREG, a Royal Decree can impose prices and volumes • A total capacity of 846.7 MW (SGR 750.0 MW/SDR 96.7 MW) was contracted for the first period (2014/2015), increasing to 1535.5 MW (SGR 1177.1 MW/SDR: 358.4 MW) for the subsequent period (2015/2016), which is supplied by the “Strategic Generation Reserve” (SGR) and	• Foreign power plants are not allowed to participate • The possibility of setting a fixed price as well as the obligation for specific power plants to participate in tendering procedure might not be compliant with current EU law (discriminatory principle, free movement rules)	Elia Group 2014, 2014, 2015a, 2015b, 2015c; Hancher et al. 2015

Objective	Administrator	Type of capacity mechanism	Capacity Agree-ment	Eligible techno-logies	Period	Description	What aspects are of special interest for the European discussion?	Sources
						the “Strategic Demand Reserve” (SDR) • Market participants that plan to shut down capacities are obliged to take part in the tendering procedure of the strategic reserve • Activation via economic (shortage of energy in day-ahead market) or technical (shortage risk) trigger • Reserve has not been activated so far • Demand side response units need to be available for up to 4 hours with an activation time of 1.5 hours		

Objective	Administrator	Type of capacity mechanism	Capacity Agree-ment	Eligible techno-logies	Period	Description	What aspects are of special interest for the European discussion?	Sources
GERMANY								
Secure the supply of electricity, if the market is unable to serve the electricity demand	TSOs in cooperation with the Federal Network Agency (Bundesnetzagentur)	Strategic reserve officially called “capacity reserve”	2-year agreements	Thermal power plants/Demand side management	Starts in 2017	• The Federal Network Agency determines the yearly size of reserve (about 5% of the estimated highest electricity load in each year) • TSOs contract capacities via public auction • TSOs determine dispatch of contracted units, which will be dispatched if the day-ahead market, the intraday market and the reserve markets cannot be cleared due to a lack of supply offers • Power plants, which leave the strategic reserve, must be shut down permanently (no way back), demand side is excluded • No penalties foreseen if contracted capacities cannot deliver	• Additionally to the strategic reserve, a network reserve has been established, in which facilities located in neighboring countries are allowed to participate as well • In the first years, the strategic reserve is supplemented by a so-called “climate reserve” (Klimareserve/Sicherheitsbereitschaft) that was established to accomplish the German climate goals and consists of old lignite-fired power plants	Federal Ministry for Economic Affairs and Energy [BMWi] 2015a, 2015b, 2016

Objective	Administrator	Type of capacity mechanism	Capacity Agree-ment	Eligible techno-logies	Period	Description	What aspects are of special interest for the European discussion?	Sources
POLAND								
Support the system in case of failure of baseload units	Polskie Sieci Elektroenergetyczne S.A (TSO)	Strategic reserve called “cold intervention reserve”	2-year agreements (with option to extend by another 2 years)	Thermal power plants that are supposed to be decommissioned	2016–2019	• Units are procured in public tenders, remuneration for capacity as well as usage • Costs of about 5 EUR/MW (24 PLN/MW gross) for every hour of keeping the units in stand-by • Maximum annual costs 174 million zloty (about 4 million EUR)	• First tender in 2013 was unable to contract sufficient capacity, hence another tender was organized in 2014 • Additionally, 200 MW demand response has been contracted, remuneration only for performance but not for availability • After 2020, the implementation of a capacity market based on the UK model is expected	Forum for Energy Analysis 2015; Hancher et al. 2015; Polskie Sieci Elektroenergetyczne Spółka Akcyjna 2015; S&P Global Platts 2016b

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SWEDEN								
• Back-up for demand peaks during the winter • Incentive for a more flexible demand	Svenska kraftnät (TSO)	Strategic reserve officially called “power reserve”	Yearly agreements	Conventional power plants/ Demand side management	Started in 2003	• Availability required between 16 November to 15 March • Volumes 2011–2013: 1750 MW 2013–2015: 1500 MW 2015–2017: 1000 MW 2017–2019: 750 MW • At least 25% of reserve needs to be demand reduction • Power plants participate in regular electricity markets with a bid price of highest regular bid + 0.1 EUR/MWh (smallest price increment) • 9 activations from 2009 to 2015 • Cost for reserve in 2014 (13 million EUR) and 2013 (14 million EUR) • Cost for a shortage situation estimated to be 90 million EUR	• Usage of strategic reserve has been harmonized with Finnish strategic reserve • Market split into 4 bidding zones, which should provide better price signals and hence reduce the required capacity for the strategic reserve • Plan to gradually phase-out thermal capacities in strategic reserve by 2020 and to rely only on demand response measures seems to be infeasible currently	Cejie 2012, 2015; ICIS 2015; Sveriges Riksdag 2003, 2010

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CENTRAL BUYER								
COLOMBIA								
Avoiding scarcity during low precipitation periods (65% installed hydro power plants capacity)	ISA (TSO)/Energy and Gas Regulation Commission (CREG)	Market wide capacity options	• Allocation of capacity starts 3 years ahead of an expected "dry year" • New power plants: up to 20 year agreements • Existing power plants: 1 year agreements	Generation capacities that could provide energy at any time (especially in dry seasons)	In 1996, first support scheme implemented, last modification in 2006	• Load Serving Entities (LSEs) have to serve their load and buy a sufficient amount of Firm Energy Obligations (in principle call options) in an auction 3 years ahead • Power plant owners receive the option premium • Additionally, the regulator defines a scarcity price for electricity • If the electricity market price is higher than the strike price, all power plants that receive the option premium must generate a given quantity of electricity. Otherwise the plant owner will be penalized. If the power plant generates more than the given quantity it will be rewarded	• Capacity mechanism for compensating electricity generation from fluctuating sources (hydro power plants) to ensure supply security in the long run • This market reduce risks to exercise market power in the electricity spot market	Cramton, Stoft 2007; Keles et al. 2016; Olaya et al. 2016

Objective	Administrator	Type of capacity mechanism	Capacity Agree-ment	Eligible techno-logies	Period	Description	What aspects are of special interest for the European discussion?	Sources
IRELAND								
Investment & generation adequacy in an island system with high share of renewables	TSOs determine the quantity to be auctioned under Regulatory Authorities' supervision	From 2017 on a volume based mechanism with centralized reliability options (Currently a price based mechanism)	1 year for existing power plants not requiring significant investment, up to 10 years for new capacity	All power plant types, also including renewable generation, demand side management	Expected start in January 2017	Range of different auctions: • Transitional auction(s): Cover the period up to the delivery year of the first T-4 auction. Little scope for new entry expected due to time constraints. • T-4 auctions. Annual auctions to procure capacity with an approximate 4-year lead time to the capacity delivery year • T-1 auctions. Annual auctions to procure capacity in the year before the capacity delivery year A certain share of the total required capacity is reserved for the T-1 auctions. This share can be adjusted, e.g. depending on the penetration of demand side management.	• Capacity mechanism will be changed from an initially price based approach to a volume based one • Multiple auctions to account for short-term as well as long-term generation adequacy	Single Electricity Market Committee 4/14/2015, 2015, 2016

Objective	Administrator	Type of capacity mechanism	Capacity Agree-ment	Eligible techno-logies	Period	Description	What aspects are of special interest for the European discussion?	Sources
ITALY								
Ensure capacity adequacy at minimum cost while considering the impact of intermittent energy sources, peak demand and regional shortages	Terna (TSO)/ Italian Regulatory Authority for Electricity Gas and Water/ Minister for Economic Development	From 2018 on a capacity market with reliability options (Currently targeted capacity payments)	*Main auction:* 3-year agreement with lead time of 4 years *Adjustment auction:* 1-year agreement with lead time of 1–3 years, TSO can adjust capacity target and capacity providers can re-negotiate obligations *Continuous trading in secondary market:* Re-negotiation of previous acquired products, 1-month	*Implementation phase (time frame currently unknown):* Dispatchable capacity on national territory not subject to other investment incentive scheme or dismantling measures *Full functioning phase:* All capacity not subject to other investment incentive	Expected start in 2018	• For each relevant zone the adequacy target is determined by the TSO from an elastic demand curve, which is a function of the Value of Lost Load (VoLL), the Loss of Load Probability and the variable cost of the marginal technology • Relevant zones are identified based on transmission constraints • Capacity will be procured in public, uniform price auctions • For each unit, the offered capacity is limited by the expected available capacity determined by the TSO • Successful bidders are awarded a premium in exchange for the following obligations ○ Offer the contracted capacity in the day ahead, ancillary services and balancing markets ○ Transfer a payment d_h to the TSO, in case, the hourly electricity price p_h exceeds a predefined strike price s_h: $d_h = cap * \max\{0, p_h - s_h\}$ where *cap* is the contracted capacity and the strike price	• Italy is one of the few European countries that experienced reliability problems in recent years (in Sardinia and Sicily, both islands that are not well connected to the mainland power grid) • According to current plans, during the implementation phase foreign capacity and demand response are not allowed to participate, however, will be factored in as offers with a price equal to zero • Rules can still be subject to change, as European Commission has yet to decide if planned mechanism is in line with EU state aid rules	Hancher et al. 2015; Italian Regulatory Authority for Electricity Gas and Water 2015; S&P Global Platts 2016a; Terna 5/14/2015

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			agreement with lead time of less than one year			s_h equals the standard hourly variable cost of the technology with the lowest annual fixed costs, e.g. OCGT • If a generator is unable to provide the contracted capacity, a fine is imposed that equals the difference between the electricity spot price and the strike price • The capacity market is financed by the dispatching users (mainly retailers) that have to pay a monthly charge. The value of this charge is equal to the difference between the premiums paid to successful bidders and the money returned to the TSO by capacity providers in case of a positive difference between the electricity spot and the strike price		

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UNITED KINGDOM								
Maintain sufficient capacity to ensure security of supply	National Grid (TSO)/ Office of Gas and Electricity Markets (Ofgem)/ Secretary of state for energy and climate change	Centralized capacity auctions	1 to 15 year agreements (existing units are allowed to bid for only one year, refurbished units up to three years if expenditure exceeds 130 GBP/kW and new units up to 15 years if expenditure exceeds 255 GBP/kW)	Conventional capacities, interconnectors and demand side response larger than 2 MW, renewables that receive subsidies (Contracts-for-Difference) are excluded	Started in 2014	• Procurement is carried out 4 years in advance (T-4 auction) • Units unable to provide contracted capacity face penalty linked to the value of lost load (VoLL) • Auction in descending clock format with uniform price, (in the first round, price is set to a price cap (NetCONE) and incrementally decreased until target capacity is reached) • The capacity is determined by the secretary of state for energy and climate change on basis of the "Electricity capacity report" provided by the TSO • Results 2015: price 18.00 GBP/kW/year, total capacity 46.4 GW, 2014: price 19.40 GBP/kW/year, total capacity 49.3 GW • For 2014/2015 a total 2.8 bn GBP of subsidies was paid	• In 2015, 650 MW of new diesel-fueled capacity was awarded contracts resulting in subsidies of 176 million GBP despite being highly emission intensive • Incentives for demand response and new investments have been limited. Of the total contracted capacity in 2015 less than 1% came from demand response and less than 2% from new investments • Foreign power plants are not allowed to participate, however cross-border transmission flows are considered in the calculation of the target capacity	McNamara 6/25/2014; Office of Gas and Electricity Markets (Ofgem) 2015, 2016; S&P Global Platts 2015a

Objective	Administrator	Type of capacity mechanism	Capacity Agree-ment	Eligible techno-logies	Period	Description	What aspects are of special interest for the European discussion?	Sources
USA – ISO NEW ENGLAND								
Promotion of economic investment in supply and demand resources	ISO New England	Forward capacity market	• Capacity commit-ment period is one year (June 1 through May 31) • Existing resources limited to one period, new resources up to seven periods	New and existing resources including power plant supply, import capacity and demand side management	Current mechanism started in 2004, initially capacity obligations have been used since 1998	• Installed Capacity Requirement (ICR) estimated as amount of capacity needed to ensure LOLE < 0.1 days • Definition of different capacity zones: Import/Export-constrained areas are assigned a minimum/maximum amount of capacity to be produced within the area to meet the ICR • Forward Capacity Auctions take place each year, approximately three years before the service period • Different qualification procedures depending on type of resource (e.g. for existing generation units the demonstrated performance over the previous five years is considered) • Two-stage auctioning mechanism: Descending-clock auction followed by auction clearing process to calculate final prices	• Technology-neutral approach with import capacities also allowed to participate • Definition of different capacity zones to account for transmission constraints • Qualification procedure for existing units based on analyses of the demonstrated historical performance by the ISO	ISO New England 2014

Objective	Administrator	Type of capacity mechanism	Capacity Agree-ment	Eligible techno-logies	Period	Description	What aspects are of special interest for the European discussion?	Sources
USA – PJM								
• Investment incentives • Ensure reliability of the system	PJM (TSO)/Federal Energy Regulatory Commission (FERC)	Forward capacity market (Market-wide)	Yearly agreements, new power plants receive payments for 3 years	• Generation resources • Load management • Qualified transmission upgrades	First delivery year: 2007/2008 (annual period from June 1 to May 31)	• Each LSE has to serve demand by own capacity, bilateral contracts or capacity purchases at the RPM market (Reliability Pricing Model). • The total required capacity in the whole system is determined by the peak load plus an additional reserve (that is about 15% of the estimated peak load) • Auctions within Locational Deliverability Areas (LDAs) • PJM calculates the capacity demand curve. The capacity price (similar to the RPM auction) is the intersection between the calculated demand curve and the supply curve. • The demand curve calculation is based on the NetCONE (Net Cost Of New Entry, i.e. the yearly fixed costs of a predefined newly built power plant minus the estimated energy and ancillary service revenues) • Penalties for non-availability of the capacity	• Complex system for achieving objectives, adjusting the capacity demand curves is mandatory. • After implementation high cash flows to already existing power plants • New investments increase the price for capacity and thus the costs for the mechanism if there is no differentiation between the products. • Through LDAs local investments could be incentivized. • Availability of the resources in scarce times must be monitored and incentivized. • Continuous adjustments are necessary that can lead to uncertainties for the investors.	Benedettini 2013; Keles et al. 2016; PJM Capacity Market Operations 2016

Objective	Administrator	Type of capacity mechanism	Capacity Agree-ment	Eligible techno-logies	Period	Description	What aspects are of special interest for the European discussion?	Sources
DE-CENTRAL OBLIGATION								
FRANCE								
Mitigating difference between peak and average power demand in winter caused by high share of electric heating in combination with rising renewable energy production	Réseau de transport d'électricité (TSO)	De-central obligation	Yearly agreements	• Technology-neutral approach • Demand response measures prioritized over generation capacity if at equal cost	Certification procedure started in April 2015, first delivery year will be 2017	• All suppliers have to hold an amount of certificates reflecting the share of electricity consumption of their consumers during peak periods, which is possible by certifying own generation and demand-side capacities or by purchasing certificates • Certification must be requested three years before the delivery year for existing generation capacity and up until two months before the start of the delivery period for new generation and demand response capacity. This allows capacities that can be developed quickly (like demand response) to also participate. • The obligation parameters, namely a security factor and an extreme temperature, are determined four years ahead of time by the TSO. The security factor takes into account the margins required to cover residual contingencies and the contribution of	• Mechanism is adjusted to the typical French load patterns with extreme peaks in winter and has to be adjusted to the respective load patterns if applied in other countries • All technologies eligible with priority granted to demand response measures • Foreign power plants are currently not allowed to participate, however cross-border transmission flows are considered in the calculation of the capacity to be certified	Hancher et al. 2015; Réseau de transport d'électricité 2014; S&P Global Platts 2015b

Objective	Administrator	Type of capacity mechanism	Capacity Agree-ment	Eligible techno-logies	Period	Description	What aspects are of special interest for the European discussion?	Sources
						interconnections to security of supply. Regarding the extreme temperature, the obligation is calculated as if one-in-ten-year cold conditions occurred every year. • Peak days, which can occur between November and March, are indicated one day ahead by the TSO. Relevant time slots are from 7am to 3pm and from 6pm to 8pm.		

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TARGETED CAPACITY PAYMENT								
GREECE								
Promotion of system flexibility to compensate for intermittent production from the high share of renewables	Greek Regulatory Authority for Energy (RAE)	Targeted capacity payments	Annual auctions of flexibility services	Gas turbines, hydropower plants, CHP units	Started on May 1 2016, other mechanisms based on capacity obligations and capacity payments have been in place since 2005	• Temporary mechanism, which is planned to be replaced by a permanent mechanism within one year • Requirements: Within three hours, ramp-up/ramp-down-rate of 8 MW/minute • Compensation: Per year 45 EUR/kW of available capacity, with a cap of 15 million EUR per production unit. Compensation is based on estimations about the additional cost resulting from cyclical power plant operation. Expected total compensation is 225 million EUR, based on an approximated eligible capacity of 5000 MW.	Explicit focus on adequate flexibility instead of considering only the available capacity	Hancher et al. 2015; Kelemenis, Sarri 2015; Todorovic Symeonidis 2016

Objective	Administrator	Type of capacity mechanism	Capacity Agree-ment	Eligible techno-logies	Period	Description	What aspects are of special interest for the European discussion?	Sources
SPAIN								
Availability service: • Ensuring short-term generation adequacy • Avoiding price volatility *Investment incentive:* • Ensuring long-term generation adequacy • Maintaining system flexibility • Reducing investment risks	*Availability service:* Red Eléctrica de España (TSO) *Investment incentive:* Comisión Nacional de los Mercados y la Competencia (CNMC)	Targeted capacity payments	*Availability service:* one-year contracts or shorter *Investment incentive:* 20 years (since 2013, before: 10 years)	*Availability service:* Thermal generation (except nuclear) and hydro (with storage) *Investment incentive:* Nuclear, gas, coal, hydro and oil	*Availability service:* Started in 2007 *Investment incentive:* 2007–2015 Before the current mechanism, capacity payments depending on fuel type and guaranteed capacity have been in place since 1997	*Availability service* (medium-term): Short-term contracts with selected power plants to keep those ready for operation during periods of peak demand *Investment incentive* (long-term): Payments to new investments which depend on the value of the reserve index (RI) in the year of initial operation of the respective power plant. RI = Available generation capacity / Peak demand. For RI < 1.1, the power plant operator receives the maximum payment, for RI > 1.29, no payments to new investments are made. Due to an extremely low electricity demand and no need for further investment in generation capacity, the maximum payment was successively reduced from initially 28 EUR/kW and finally completely abolished in 2016.	• Administrative price-setting bears risk of incentivizing too many investments • Unforeseen events make it difficult to estimate the required generation capacity. In 2013, capacity payments for new investments were abolished for power plants entering into service after 1 January 2016 due to an economic crisis and the resulting low electricity demand. • Yearly adjustment of payments increases investment risk • Approach of reaching short-term and long-term generation adequacy with two different mechanisms	European Commission 2016; Hancher et al. 2015; Villaplana Conde 3/20/2012

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