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strategy&

Unlocking Industrial Demand Side Response

TenneT

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pwc

Content

Foreword

The continued increase of variable wind and solar PV generation requires flexible resources to balance demand and supply in the electricity system. Flexibility providers include conventional generation plants, storage systems, and demand response entities (or demand flexibility). Thus far, conventional – mostly gas-fired – power plants have been the dominant flexibility resource. However, as their economics are affected by a progressive reduction of operating hours and an increasing ETS CO_2-price, the business case for both storage systems and demand response is likely to improve over time. Among these two categories, demand side response is the lesser known and the subject of this highly appreciated study.

A substantial capacity of demand side response (DSR) has been active in the Dutch electricity market since many years, in particular in the industry. The need for flexibility will only increase by the increasing variability in the electricity system and emerging electrification in various sectors. The major energy consumption and large-scale nature of the industry sector is likely to offer sizeable new potential for demand response. While several studies have tried to quantify this potential for demand response, the extent to which DSR is likely to be unlocked is not a given. This will not only depend on market prices, but also on factors such as market design, regulatory hurdles, technology maturity and experience. TenneT aims to contribute in optimising these factors to fully unlock the potential for industrial demand response to the benefit of the system in order to secure a reliable, sustainable and affordable electricity system.

Maarten Abbenhuis
Chief Operating Officer

Foreword

Due to the nature of the future electricity system, two categories of demand response are distinguished in this study. Firstly, the day-to-day variability of both renewable generation and the demand cycle, make storage systems and low-cost demand response potentially attractive options. Secondly, at the time of very high electricity consumption and low electricity generation by wind and sun, demand response can play a key role in ensuring security of supply. Since the latter event is relatively rare, an additional volume of demand response could be more cost effective than the likely alternative: a back-up conventional power plant (at least for the coming decade).

Objectives of this study are twofold. Firstly, it will provide an up–to-date overview of demand response capacity in industry for specific European countries. Secondly, it will present an overview of measures (i.e. government policies and market mechanisms) in the electricity market model to incentivise industrial DSR in these countries.

The findings of this study will help TenneT to stimulate the development of industrial demand side response. These findings can also serve as a basis for a constructive dialogue with industry stakeholders to help their thinking about developing new demand response potential.

We aim to increase awareness and demonstrate the opportunities offered by DSR. Interviews with industries across countries demonstrate the challenges.

Analysis of the observations have led to four key guiding principles that need to be fulfilled in order to fully unlock industrial DSR potential:

- **Market access**: Electricity markets should be accessible for industrials either independently or through an aggregator of choice.
- **Economic attractiveness**: Clear, transparent, and timely (price) information must be provided, a fair and transparent pricing mechanism should be in place and financial disincentives should be avoided.
- **Market participation**: Industries must be fully aware of the opportunities iDSR can offer and markets should be designed to optimize participation.
- **Operations and enforcement**: Metering requirements and pre-qualification methods should not unduly hinder iDSR.

Industrial DSR is increasingly important as a source of flexibility, and yet we recognise an international struggle to fully unlock its potential. TenneT can really benefit from boosting awareness and removing unintended barriers that will enables us to drive the energy transition.

Maarten Abbenhuis
COO TenneT

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Executive summary

Together with TenneT, we performed a pan-European study on industrial DSR as a source of flexibility to balance the grid

Introduction

- To accommodate the growth of decentralized renewable energy supply and an increasing energy demand due to electrification of heat and mobility, TenneT needs to further enhance and arm its grid
- Over the coming decade, TenneT will invest almost €40bn[1] in its networks to cope with the energy transition, resulting in a tripling of the balance sheet
- In addition to these investments, ensuring a high degree of flexibility into the system is crucial to cope with the consequences of the energy transition in an efficient and cost effective way
- There are four types of flexibility that TSOs can leverage: (i) generation capacity (mainly dispatchable thermal power); (ii) interconnection capacity; (iii) storage facilities; and (iv) Demand Side Response ("DSR")
- With DSR, electricity end-users shift or shed their load based on price signals or incentives, which can help in balancing supply and demand
- This study focuses on DSR provided by industrials ("iDSR") – a segment that is already actively contributing to balancing the grid. Ongoing electrification and digitization of industry is projected to grow iDSR potential in Europe from 100 GW in 2019 to 160 GW in 2030[2], equivalent to the current combined installed capacity of the Netherlands and France[3]
- Today, already a fifth of this potential is actually participating.[2] Further unlocking iDSR offers significant opportunity to increase flexibility

Objectives of this study

TenneT has requested Strategy& (part of PricewaterhouseCoopers Advisory N.V.) to inform TenneT's thinking on practices, market mechanisms and national policies (together further referred to as 'measures') that can help to unlock iDSR capacity in the Netherlands and Germany. Professor Michael Pollitt of Cambridge University acted as academic advisor to the project team. Insights from this study will form a basis for constructive dialogue with industry stakeholders and national regulatory authorities.

TenneT is interested in understanding which measures United Kingdom, France, Belgium, Denmark and Spain have taken, or will take, to unlock industrial DSR capacity and what can be learned from that. To get a good understanding of successes and failures of industrial DSR in other countries, this report provides a perspective on the following topics for the countries in scope:

1. Provide an up-to-date quantitative overview of active and potential industrial demand side response capacity categorized per sub-sector and type of use (frequently vs. seldomly)
2. Provide an overview of current, proposed or abandoned practices, market mechanisms, national policies and DSR participation rates in the electricity market model (including whether these are included in adequacy analyses)
3. Provide an overview of the degree of effectiveness, success, potential improvements, barriers and likely trends in industrial DSR over the next 10 years, from a multi-stakeholder perspective (including known issues and debates)

Source: 1) TenneT Annual Report; 2) SEDC (2017, a); 3) TenneT internal data; Strategy& research

Industrial DSR is increasingly important as a source of flexibility and countries are striving to unlock more of its potential

Executive summary (1/2)

Declining sources of traditional flexibility, increased RES generation and growth in electricity demand, raises the need for other types of flex, such as industrial DSR

- Installed capacity, technology mix, interconnections and demand profiles, in aggregate determine the degree of flexibility that is available in the grid. With flexibility we refer to the options (both in timing and magnitude) a TSO has to balance supply and demand of electricity at a given time
- The confluence of declining sources of traditional flexibility – dispatchable thermal power generation – and increased weather-driven RES and growth in electricity demand (due to electrification of heat / mobility), result in a greater need for flex, whilst the sources for this flex are in retreat. Unlocking alternative sources of flex, like Demand Side Response ("DSR"), is therefore increasingly important and valuable for TSOs
- Industry accounts for a significant part of electricity demand, with percentages ranging between 26-44% in the countries in scope, indicating its substantial potential for providing flexibility through industrial DSR ("iDSR")

Substantial potential of iDSR is widely acknowledged and supported, however only a fraction is unlocked yet

- Demand Side Response can be differentiated in implicit and explicit DSR, with the former being unilaterally adjusting power consumption based on market prices, while the latter is actively, bilaterally offering flexible capacity on the market
- The European Commission recognizes the importance of DSR for the European electricity system and is stimulating its unlocking over the past years – emphasized once more with its recently introduced "Clean Energy Package" (CEP)
- All markets we examined in this study have significant iDSR potential (ranging from 10-17% of peak load), however universal terminology and methodology is lacking, making cross-country comparisons difficult
- Companies with sizeable electricity consumption, non-continuous production processes and the possibility to buffer heat or products, are best positioned to participate in iDSR (e.g. food, plastic, paper, glass, chemicals and metal industries)
- While only a fraction of the iDSR potential is unlocked in all markets we examined, countries are actively encouraging DSR and we investigated their maturity

Using desk research and expert interviews, we gathered measures, mechanisms and policies that impacted unlocking of iDSR in seven European countries

- This study assessed the maturity of industrial DSR in seven European countries that were carefully selected by TenneT: the Netherlands, Germany, the United Kingdom, Belgium, France, Denmark and Spain
- We gathered the measures, mechanisms, and policies, impacting the unlocking of iDSR in these countries through both desk research and expert interviews (with TSOs, NRAs, aggregators, industrials and stakeholder organizations). Our country observations were grouped along four axes: market access; economic attractiveness; market participation; operations and enforcement

Market access

Do industrials have, directly or indirectly, access to the relevant electricity markets, so they are adequately enabled to participate in both implicit and explicit DSR?

Economic attractiveness

Are markets providing the right incentives to industrials to participate in DSR and do they enable them to build an attractive business case around this?

Market participation

Are markets designed in such a way that they maximize participation in DSR, by removing potential barriers and adapting to the preferences of industrials?

Operations and enforcement

Do operations and enforcement fully enable and facilitate industrial DSR, by providing the right tools and incentives?

Analyzing of these cross-country observations have led to four key guiding principles per axis that need to be fulfilled in order to fully unlock iDSR potential in a country

- *Market access:* electricity markets should be accessible for industrials and opened for both implicit and explicit iDSR, either independently or through an aggregator of choice
- *Economic attractiveness:* there should be provision of clear and timely (price) information, a fair and transparent pricing mechanism, and avoidance of financial disincentives
- *Market participation:* Industrials must be fully aware of the opportunities iDSR could offer, and markets should be designed to optimize participation
- *Operations and enforcement:* metering requirements and pre-qualification methods should not unduly hinder iDSR, and penalties are regarded as reasonable and provide the right incentives to industrials

The Netherlands and Germany could benefit from boosting awareness and finalizing full market integration of iDSR

Executive summary (2/2)

In the Netherlands and Germany, industrials are already providing substantial DSR flexibility through wholesale and balancing markets[2]:

- Current iDSR participation in the Netherlands is estimated at 0.7 GW (compared to 3.4 GW theoretical potential)[1]
- In Germany, industry currently mainly participates through the interruptible load program with 1.0-1.5 GW capacity

Based on the observations across Europe, certain aspects stand out in the Netherlands. To enhance iDSR, it could be relevant to focus on the following matters:

- The Netherlands provide discounts on network tariffs (up to 90%) for a stable consumption pattern, which creates a significant disincentive for participating in DSR
- Too many industrials are still not aware of the possibilities regarding DSR. They indicate a need for decent information channels and a dedicated go-to person. The Power Responsive program in Great Britain is a good example of how countries are investing in raising awareness. The program increases the awareness of DSR among industrials and shapes the growth of the market in a collaborative way. This ensures that the demand side has equal opportunity with the supply side when it comes to balancing the system. Another possibility may be to organize an annual DSR survey among industrials to generate insight into their motivations, help in understanding specific regulatory barriers, and stimulate awareness among industries regarding DSR and its benefits
- With many industrials new to DSR, aggregators can play a vital role in industrial DSR, because they facilitate participation by reducing complexity and mitigating risks. Industrials are not always willing to collaborate with aggregators due to lack of transparency or misconception about their role. It is important that industrials feel confident about the service they receive from the aggregators. This may be facilitated by a common set of standards and independent auditing on aggregators. In Great Britain, the ADE created an independent Code of Conduct for DSR aggregators through which DSR providers can compare aggregators and their claims
- (Sub)metering requirements tend to be quite strict, to prevent non-accountability in imbalances. However, the requirements are so strict that practically no submeters can be used in the settlement process, limiting the opportunities for aggregation and thus the unlocking of DSR capacity

Whilst having made good progress in recent years, there remain some focus areas, in addition to the Dutch matters, which Germany could potentially improve on:

- Several markets (e.g. capacity reserve balancing product) are closed for DSR, either because legislation prohibits participation, or by being closed in practice due to generation-biased product design (e.g. network operators are too risk averse to open certain products to DSR). Consequently this may be hindering the market access
- Germany uses both ‘Pay-as-Cleared’ and ‘Pay-as-Bid’ mechanisms for its balancing products, whereas the latter may result in (too) low prices for industrials reducing the participation rate. However, this is partly mitigated by the fact that – as opposed to the Netherlands – Germany has a capacity mechanism, which rewards industrials for having their flexible capacity on standby in addition to the payment for delivered electricity, generally improving industrials’ business case
- Due to the relatively large share (50-80%) of the total retail price consisting of taxes and grid charges, price signals to DSR providers may be diluted resulting in less DSR participation

Interviews with industrials across countries confirm the challenges they face, which are:

- Industrials confirm that they have low awareness of opportunities of DSR. Parties indicate they would benefit from improved access to information and dedicated contact persons to support the understanding of the needs and opportunities in this market
- There are many uncertainties industrials face regarding developing the DSR business case, such as future power imbalance price volatility, changing regulation, variation in DSR product/service, upfront investments and split revenues with aggregators
- There are also operational uncertainties among the industrials, including logistical challenges, e.g. integrated planning, safety risks and training of personnel, and technical challenges e.g. unqualified (sub)meters, obsolete assets, minimum bid sizes and response time

1) Source: DNV GL (2020); 2) This document repeatedly refers to ‘balancing market’ as being balancing energy and – where applicable – capacity markets

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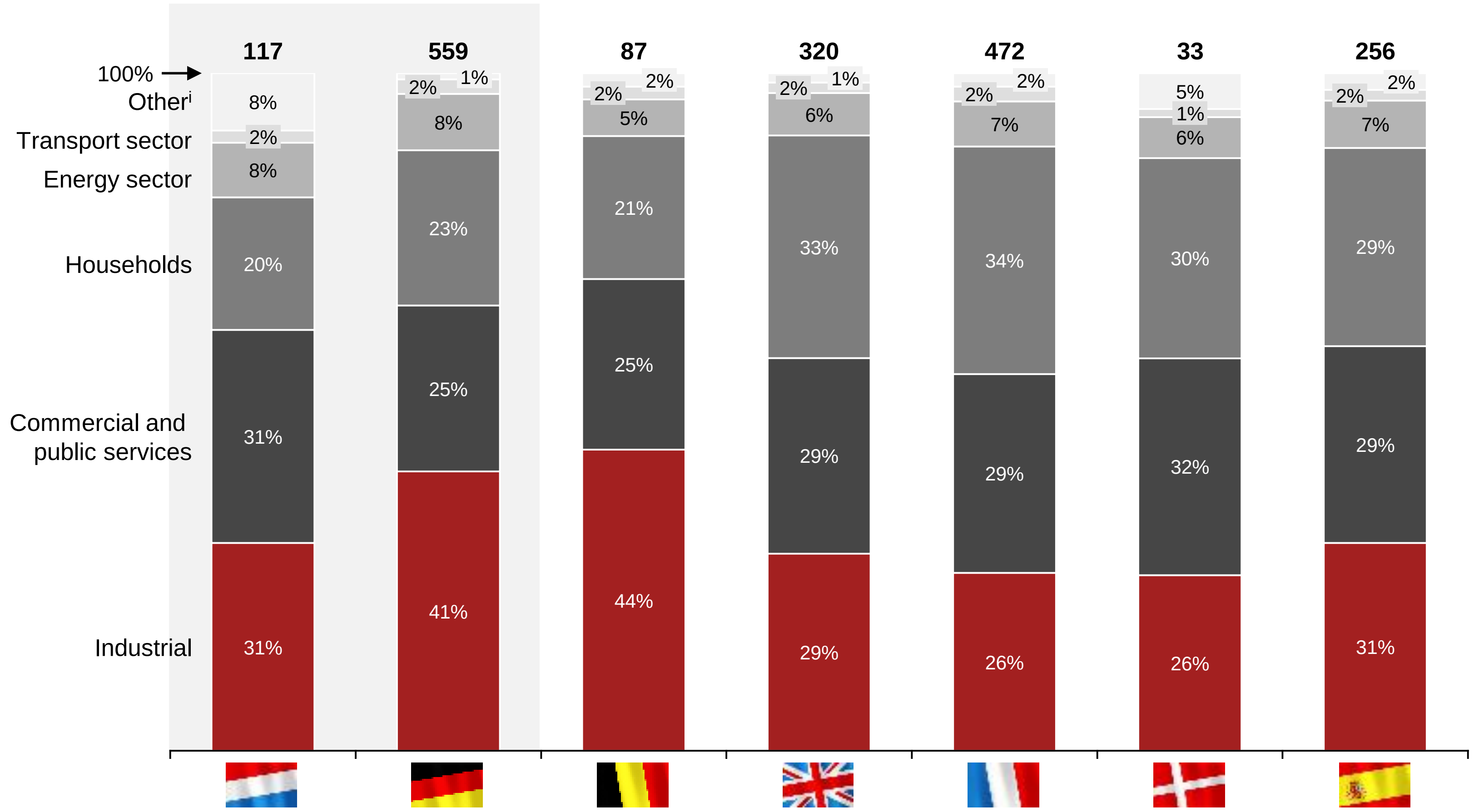
Power market overview

Industry accounts for a significant part of electricity demand, indicating its potential for contributing to flexibility

Electricity demand by sector *(2018, in % and TWh)*



Insights

- The share of **industrial** electricity demand from the total **varies significantly** from country to country
- A relatively **higher share** of industry in total electricity demand, indicates **more** industrial DSR **potential**
- **Denmark, France, United Kingdom** and **Spain** have a relatively high share of electricity consumption for households (due to large share of electric heating / cooling), which potentially limits flexibility due to more rigid consumption patterns
- In **the Netherlands**, energy consumption of ‘other’ can be attributed almost entirely to agriculture, due to **large horticulture industry.** They are already an active provider of flexibility due to their sizeable **CHP-installations** of typically ~10 MW

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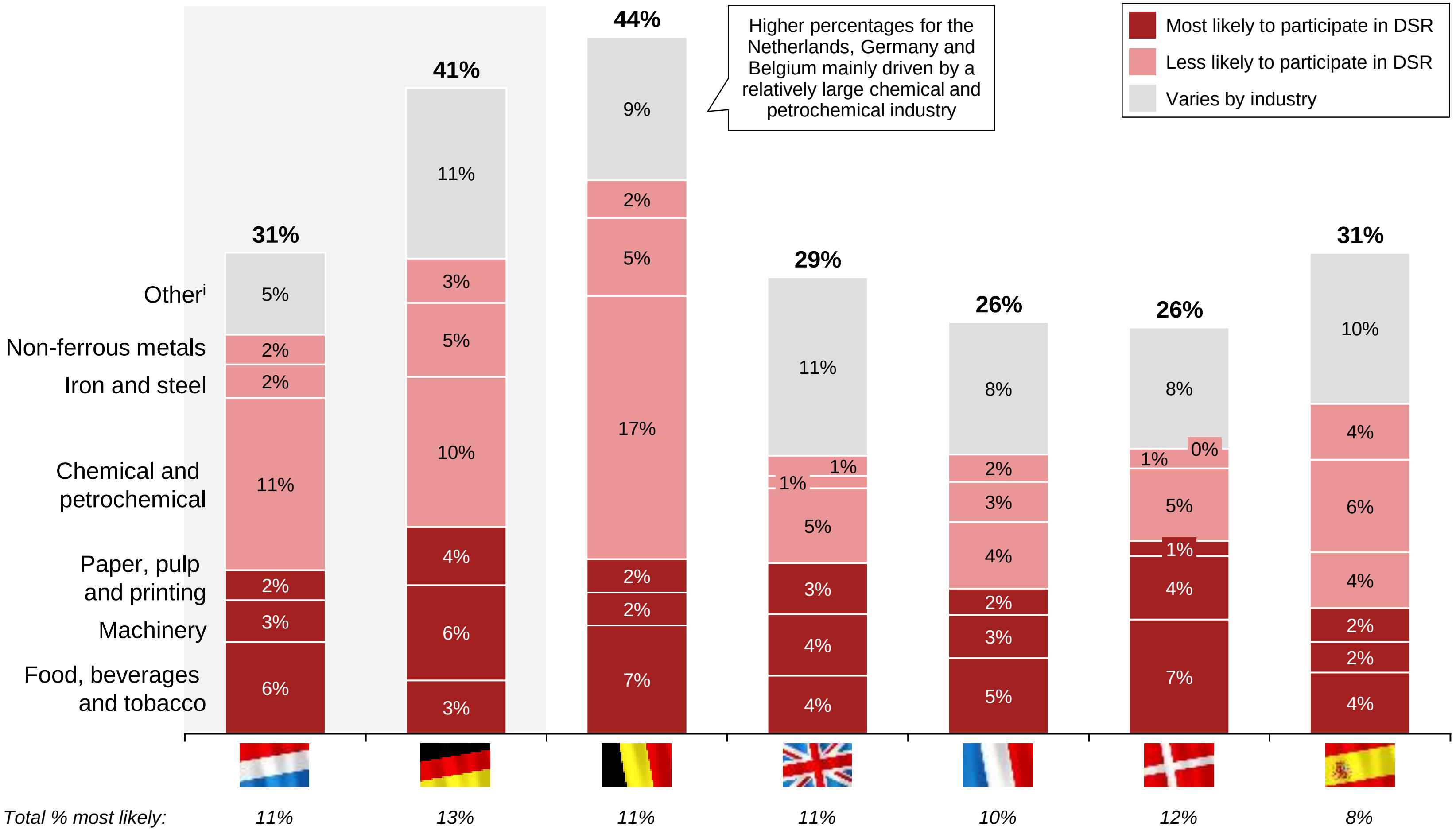
i) Other includes: agriculture, forestry and fishing

Source: Eurostat (a); Strategy& analysis

Share of industrial electricity demand is driven by underlying industries, however, not all are likely to participate in DSR

Industrial electricity demand by industry as % of total demand *(2018, in %)*[1]



Higher percentages for the Netherlands, Germany and Belgium mainly driven by a relatively large chemical and petrochemical industry

🟥 Most likely to participate in DSR
▨ Less likely to participate in DSR
⬜ Varies by industry

Insights

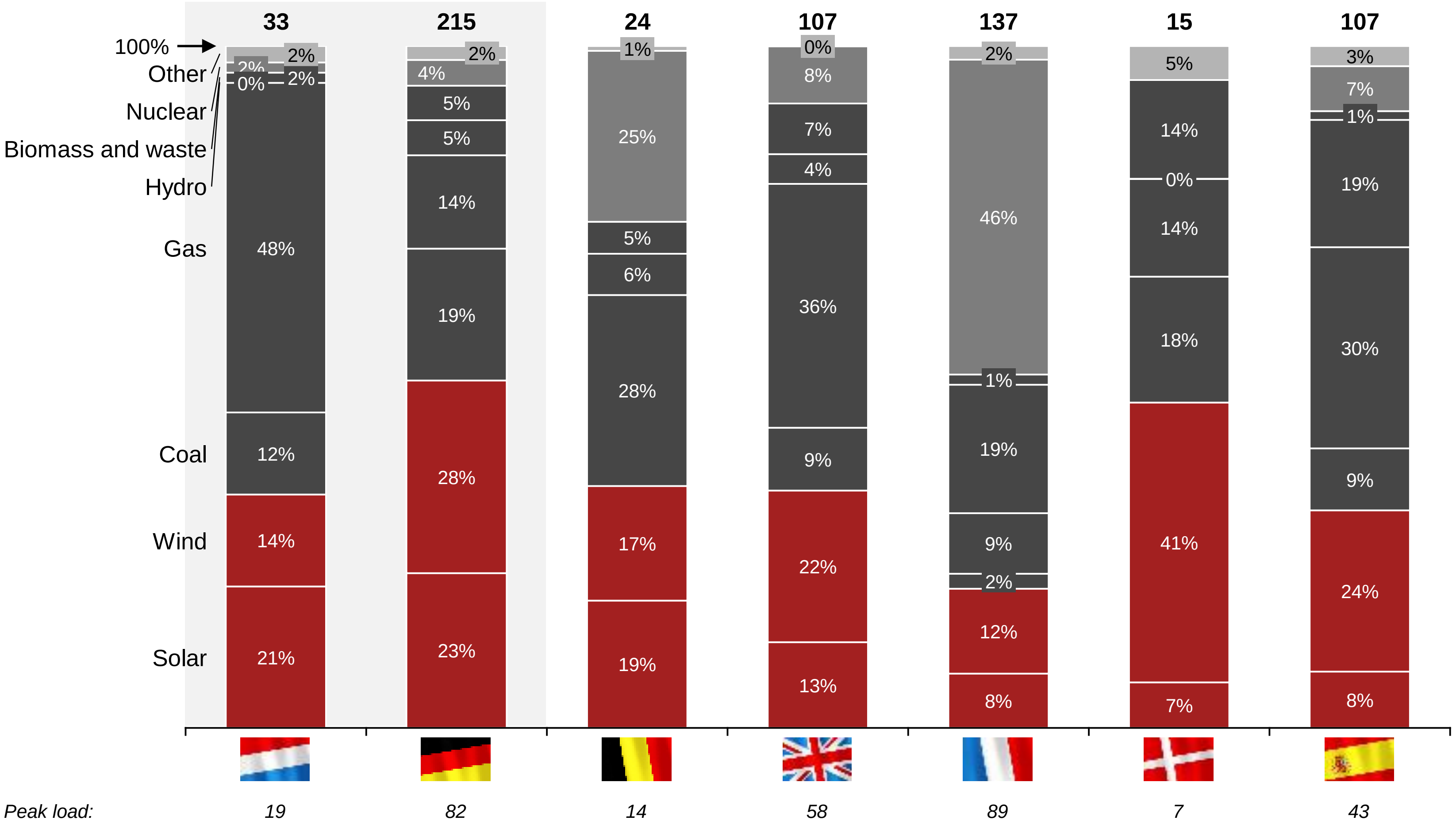
- The flexibility per company **depends on various factors** that are mainly related to its **production process** (e.g. utilization rate, possibility to buffer) and **type of assets** (e.g. response time)
- The **food**[3], **machinery** and **paper industry**[4] typically have processes that are suitable to provide flexibility as they can **buffer production**, which makes companies active in these industries **most likely** to participate in DSR
- **Chemicals**[2], **steel** and **other metals** have typically (near) **continuous processes** which require sophisticated planning capabilities, which makes companies active in these industries **less likely** to participate in DSR
- However, there are some exceptions to the rule, e.g. **aluminum smelter** is very suited to participate in DSR due to its ability to shed load without loss of quality

i) Other includes: non-metallic minerals, transport equipment, construction, textile and leather, wood and wood products, and mining and quarrying

Source: 1) Eurostat (a); 2) Otashu and Baldea (2019); 3) Clairand et al. (2020); 4) Herre et al. (2020); Strategy& analysis

Installed capacity determines to a large extent the flexibility to balance the grid; the Netherlands relies on ~50% for gas*

Installed capacity by production type *(2019, in GW and %)*



Insights

- Electricity generation can be classified as **intermittent** (solar, wind), **dispatchable** (coal, gas, hydro, biomass and waste), **nuclear** and **other** (e.g. oil, geothermal)
- **Dispatchable** generation is regarded as a **flexible** source of electricity, whereas the flexibility of **intermittent** generation depends on the weather conditions
- Countries with relatively **low shares** of **dispatchable** generation (**Germany, Belgium,** and **France**) are most likely in need of extra flexibility capacity - especially when this is accompanied with significant intermittent generation (**Germany**)
- **Nuclear** is typically seen as partially dispatchable, due to limited agility in changing its production; **Belgium** and **France**, who rely on substantial nuclear capacity, therefore need additional flexible capacity to accommodate this

* Excluding interconnection capacity
Source: TenneT internal data; Strategy& analysis

⬜ Other ⬜ Nuclear ⬛ Dispatchable 🟥 Intermittent

Availability and characteristics of different production types dictate the degree of flexibility of generation assets

Flexibility of generation assets

▨ Nuclear ■ Dispatchable 🟥 Intermittent

🟥 Typically ▨ Outliers

Type	Description	Plant size *(in MW)*	De-rated factor[1]	Availability[2]	Flexibility[3]
Nuclear	Nuclear generation cannot be qualified as 'dispatchable' nor as 'non-dispatchable', as it's **controllable within certain limits** (i.e. longer adjusting times, less agile)	*500 – 1,000* *2,000 – 5,000* 0 5,000	88%	◕ In general available, except for (un)planned outages	◕ Less flexible than dispatchable, due to longer adjust times and no marginal cost
Biomass and waste	There are both **standalone** biomass plants and **co-fired** coal plants, which are both typically limited in size	*10 – 1,000* 0 5,000	81%		● In general fully flexible, as they can typically provide flex in both directions (when not fully utilized) on very short notice
Hydro	Hydro is a very **efficient** form of flexible capacity in countries with the **right geographical** characteristics	*10 - 100* *1,000 – 3,000* 0 5,000	84%		
Gas	Gas and coal are **flexible** resources, that can be dispatched on demand Due to **transition from fossils to renewables**, there will be a phasing out of gas and coal fired power plants, which will significantly **reduce flexible capacity**	*250 - 750* *1,000 – 3,000* 0 5,000	87%		
Coal		*250 - 750* *1,000 – 3,000* 0 5,000	88%		◕ Older coal power plants are less flexible due to longer response times
Wind	Intermittent source of generation, which makes it **less suitable** as (upward) flexible capacity However, **curtailing** generation can provide substantial **downward flexibility**	*50 - 700* 0 5,000	11%	◔ Depending on location, wind has 2,000–3,500[4] full load hours p.a. (20 – 35%)	◑ Intermittent sources can only provide downward flexibility
Solar		*5 - 50* 0 5,000	1%	◔ Depending on location, solar has 800 – 1,200 full load hours p.a. (10 – 15%)	

1) De-rated factors, calculated by analyzing historical availability performance of the different generation technologies during peak periods, are used to de-rate installed capacity; 2) Availability shows how much percent of time a resource can generate electricity; 3) Flexibility is determined by direction, response time, and notice time, in which assets can provide flex to the grid; 4) Offshore wind can reach ~4,500 hours; Source: Ofgem (2014), p. 14; National Grid (2019), p. 3; Elia (2019, c), p. 19; Strategy& analysis

In addition, Demand Side Response, storage facilities and interconnections can provide flexibility to the system

Other sources of flexibility

Source	Description	Timeframe	De-rated factor[1]	Availability[2]	Flexibility[3]
Demand side response	• Demand Side Response can potentially offer flexibility in **both directions**, within **all timeframes** and with quite a **high reliability**, as the de-rated factor is 86% • This high de-rated factor is only applicable to currently unlocked DSR, we're not sure whether that still holds for all potential DSR	✓ Sec. ✓ Min. ✓ Hours ✓ Days ✓ Weeks	86%	◕ Availability is comparable to dispatchable generation assets	● All these sources are fully flexible, as they can provide flexibility in both directions (except when storage is fully charged), on short notice
Storage (e.g. batteries, pumped up hydro, compressed air)	• Storage is by far the **most reliable source of flexibility** with a de-rated factor close to 100% • While storage can facilitate flexibility in **both directions**, it can typically only be used on the shorter time frames (**up to several hours**), with pumped up hydro providing max. several days flexibility capacity	✓ Sec. ✓ Min. ✓ Hours ✓ Days Weeks	97%	● Storage is typically regarded as almost always available, as maintenance is rarely needed	
Interconnections	• Interconnections with other countries can provide **significant** flexible capacity in **both directions** and on **all timeframes** • However, due to **overlapping consumption** and **weather patterns** between adjacent countries and **(un)planned outages**, the de-rating factor is low, as you are dependent on availability of electricity in the other country	✓ Sec. ✓ Min. ✓ Hours ✓ Days ✓ Weeks	Conservative estimate; actual figures vary heavily by country and interconnector 50%	◑ Due to overlapping weather and consumption patterns, installed interconnector capacity typically cannot be used to its full extent	

1) De-rated factors, calculated by analyzing historical availability performance of the different generation technologies during peak periods, and used to de-rate installed capacity; 2) Sources are not available at all times due to (un)planned outages or (overlapping) weather conditions; 3) Sources are almost perfectly flexible, as they all can provide flexibility in both directions; Source: Ofgem (2014), p. 14; National Grid (2019), p. 3; Elia (2019, c), p. 19; Pöyry (2019), p. 3; Strategy& analysis

Electrification of heat/mobility drives electricity demand and transition from fuels to RES increases intermittent generation

Key trends in electricity demand and supply

	Development
Demand-side	**Electrification of heat in industry** (up to ~400 °C), resulting in a shift from gas to electricity
	Increasing use of **heat pumps** in built environment, resulting in a shift from gas to electricity in most countries
	Electrification of mobility requires **charging infrastructure for EVs**, which will boost electricity demand
	On the longer term, **blue** and **green hydrogen** production will require significant amounts of electricity[i]
Supply-side	Increasing **wind and solar** generation, drives intermittent generation as % of total installed capacity
	Phasing out from **fossil fueled power plants**, reduces dispatchable generation as % of total installed capacity, potentially offset on the longer term with hydrogen plants
	Number of countries develop new **interconnectors**, increasing interconnection capacity in Europe[i]
	Increasing focus on batteries and pumped up hydro, drives **storage capacity** as % of total installed capacity[i]

Increasing need for flexibility:

- Increased demand for electricity will result in **greater average demand** and **increasing peak load**
- Particularly **during periods of low RES** generation flexibility is needed, since a relatively low peak load can already cause problems
- Electrification of heat and mobility causes **load profiles** to change and introduces new ones (e.g. single PV, single EV, EV + PV, etc.)
- Transition from fossils to intermittent RES, making generation **more weather-dependent**

Changes in flexibility:

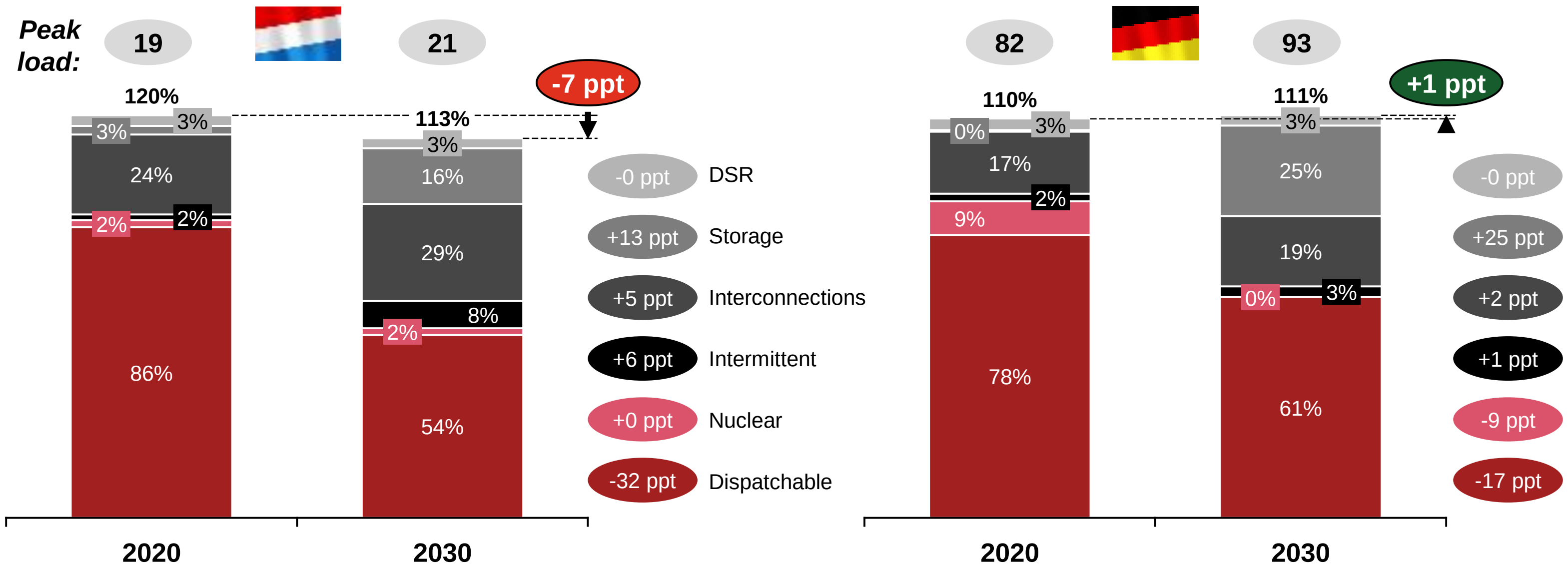
- Phasing out of dispatchable generation, **decreases** flexible capacity
- Improving interconnections in North-West Europe, **increases** flexible capacity
- Rising storage capacity, **increases** reliable flexible capacity

i) Can be both demand- and supply-side, depending on the situation
Source: Strategy& research

Illustrative

These trends and projected installed capacity result in flexibility to decrease in Netherlands (-7 ppt) and stay stable in Germany (+1 ppt)

De-rated flexible capacity as % of peak load Netherlands and Germany *(2020 and 2030, in GW and %)*



- **Peak load** projected to increase from 19 to 21 GW[4]
- **Dispatchable capacity** will decrease as % of peak load, due to phasing out of coal and (partially) gas[5]
- **Intermittent** generation will increase as % of peak load due to +30 GW wind and solar PV in the pipeline[5]
- **Interconnections** will increase as % of peak load due to 2.7 GW additional capacity in planning[5]
- **Storage** will increase as % of peak load due to ~3 GW projected additional storage (incl. EV capacity)[5]

- **Peak load** projected to increase from 82 to 93 GW[9]
- **Dispatchable capacity** will decrease as % of peak load, due to (partial) phasing out of coal from 17 to 7 GW[5]
- **Nuclear** will decrease as % of peak load, due to termination of the nuclear power plants by 2030[5]
- **Storage** will increase as % of peak load, due to ~24 GW projected additional storage facilities (incl. EV capacity)[8]

Remarks on methodology

- De-rated flexible capacities are estimated by multiplying the **de-rated factors** with the current (2020) and projected (2030) installed capacities by flexible source and country
- We **assume current DSR participation to remain constant***, to estimate the impact on flex without any progress on unlocking industrial DSR potential
- As actual de-rated factors vary highly by country and no single source for installed capacities could be used, figures shown are for **illustrative purposes** only and **cannot be compared across countries**
- However, a **comparison over time by country** can be made, as a consistent methodology is used
- Therefore, a **relative comparison** of the figures by country over time is insightful, whereas the absolute numbers are inconclusive on a country's ability to handle peak load with their flexible capacity
- Lastly, **peak load figures** per country are typically not gathered from the same source, which forms a caveat as underlying methodologies might differ and projections are subject to assumptions

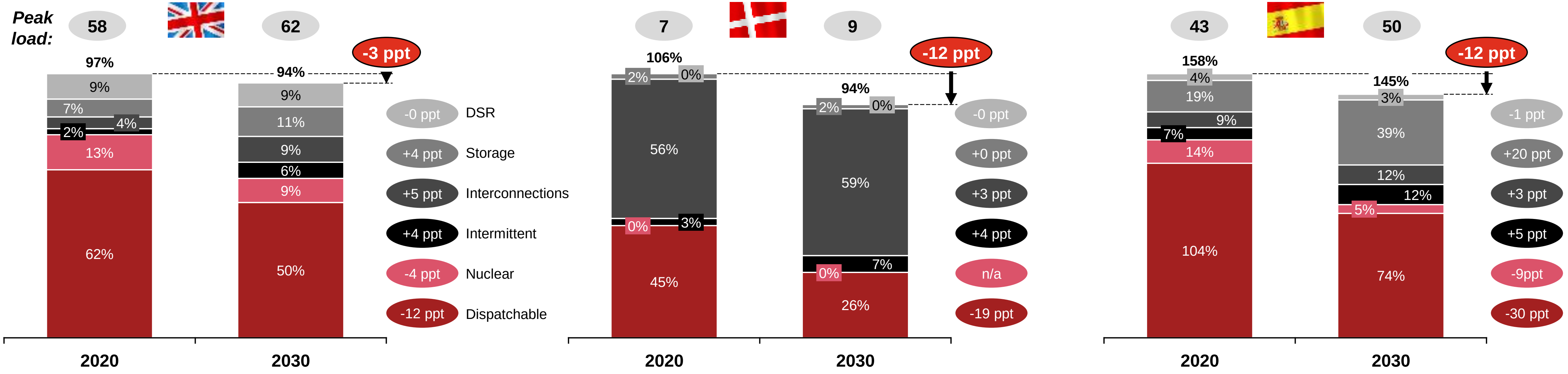
* Percentage point differences shown are therefore solely resulting from changing peak load

Source: 1) TenneT (2019); 2) TenneT (a, b); 3) European Commission (2018); 4) E-CUBE (2020); 5) DNV GL (2020); 6) Valdes et al. (2019); 7) BMWi (a); 8) Clean Energy Wire (2019, a); 9) Wirtschaft NRW (2018); Strategy& analysis

Illustrative

Decreasing dispatchable capacity causes flexibility to worsen in United Kingdom (-3 ppt), Denmark and Spain (both -12 ppt)

De-rated flexible capacity as % of peak load United Kingdom, Denmark and Spain *(2020 and 2030, in GW and %)*



- **Peak load** projected to increase from 58 to 62 GW[4]
- **Dispatchable capacity** will decrease as % of peak load, due to phasing out of coal and decline of gas with 3 GW[1]
- **Nuclear** will decrease as % of peak load, due to the decommissioning plan of nuclear power plants[1]
- **Interconnections** will increase as % of peak load, due to additional interconnectors of 3.8 GW in the pipeline
- **Storage** will increase as % of peak load, due to ~3.0 GW projected additional storage (excl. EV capacity)[3]

- **Peak load** projected to increase from 7 to 9 GW[12,13]
- **Dispatchable capacity** will decrease as % of peak load, due to a reduction in gas fired power plants by 1.0 GW[10,11]
- **Intermittent** will increase as % of peak load, due to additional 3.9 GW solar and 3.2 GW offshore wind[10,11]
- **Interconnections** will increase as % of peak load, due to additional interconnectors of 2.8 GW in the pipeline[8]
- **Storage** ambitions remain unclear, although they aim to have 775k EVs by 2030, which could provide flex[9]

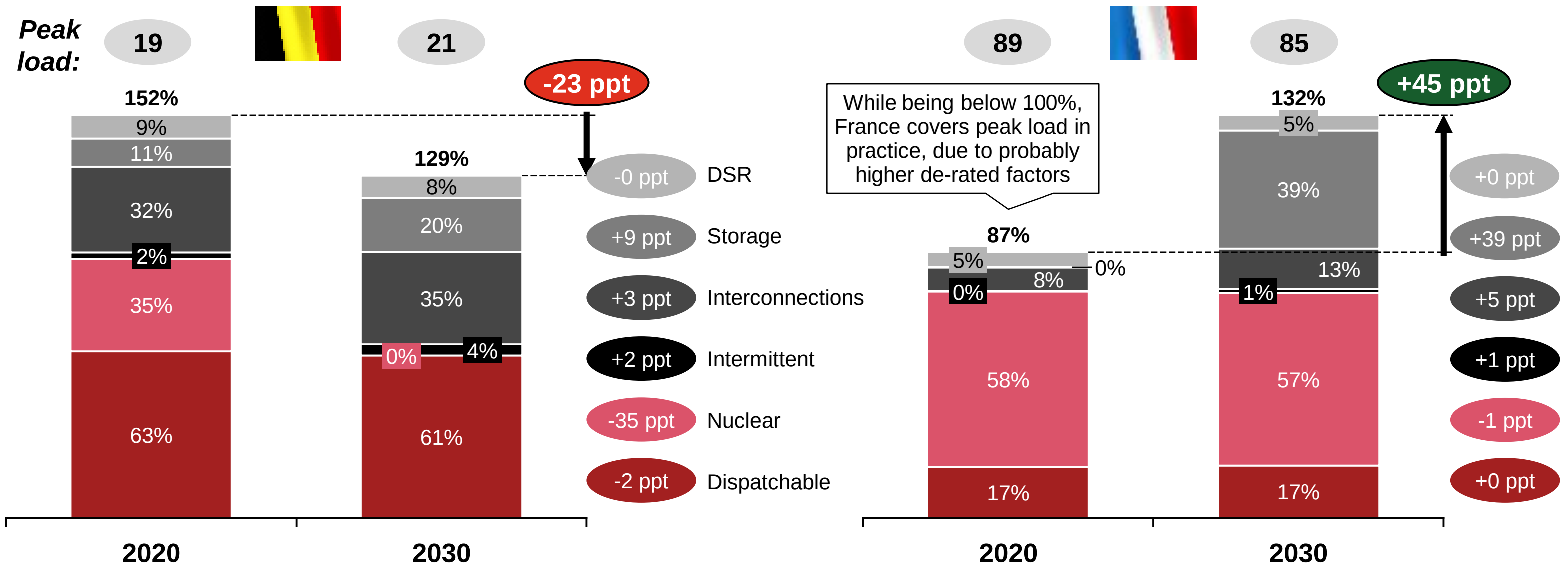
- **Peak load** projected to increase from 43 to 50 GW[14,15]
- **Dispatchable capacity** will decrease as % of peak load, due to a reduction of coal fired power plants by 8.1 GW[16]
- **Nuclear** will decrease as % of peak load, due to reduction of nuclear power plants by 3.4 GW[16]
- **Intermittent** will increase as % of peak load, due to additional 0.5 GW solar and 2.5 GW wind[16]
- **Storage** will increase as % of peak load, due to ~12 GW projected additional storage (excl. EV capacity)[17]

Source: 1) DNV GL (2020); 2) European Commission (2019); 3) Pöyry (2017); 4) BEIS (2020, b); 5) National Grid (a); 6) ESN (2020); 7) REE (a); 8) Danish Ministry of CUE (2019,a); 9) Reuters (2020); 10) ENTSOE (e); 11) ENTSOE (f); 12) E-CUBE (2020); 13) Agora (2015) – assuming a steady growth from 2014 to 2020 in Danish peak load; 14) Deloitte (2015); 15) Deloitte (2016); 16) European Commission (2019); 17) Energy Storage News (2021); Strategy& analysis

Illustrative

Phasing out of nuclear in Belgium will reduce flexibility (-23 ppt), whereas France improves significantly due to new storage (+45 ppt)

De-rated flexible capacity as % of peak load Belgium and France *(2020 and 2030, in GW and %)*



While being below 100%, France covers peak load in practice, due to probably higher de-rated factors

- **Peak load** projected to remain approximately the same[3]
- **Nuclear** will decrease as % of peak load, due to termination of nuclear power plants by 2030[1]
- **Interconnections** will increase as % of peak load, due to additional interconnectors of 1.0 GW in the pipeline[2]
- **Storage** will increase as % of peak load due to doubling of current storage capacity from 1.5 to 3.0 GW (incl. EV capacity)[3]

- **Peak load** projected to decrease from 89 to 85 GW, mainly due to the transition from resistance heaters to heat pumps[7,8]
- **Interconnections** will increase as % of peak load, due to additional interconnectors with among others Spain, Germany and Ireland of 9 GW in total[5]
- **Storage** will increase as % of peak load, due to ~34 GW* projected additional storage (incl. EV capacity)[9,10]

DSR in national adequacy assessment

- In countries were DSR is more mature, TSOs include its capacity in their national adequacy assessment (i.e. as a reliable source of flex)
- The table below presents an overview of the countries that have done this and in what way

🇳🇱	✓	TenneT included 700 MW of DSR capacity in their 2020 annual adequacy assessment[11]
🇩🇪	~	BNetzA included a section on DSR in its 2019 adequacy assessment, however without mentioning specific capacity figures[13]
🇧🇪	✓	Elia included 1,400 MW of DSR capacity in their 2019 adequacy assessment[12]
🇬🇧	~	NG included DSR capacity in their 2019 annual security of supply report - however only the capacity market capacity is included[14]
🇫🇷	✓	RTE included 2,9 GW DSR capacity in their 2019 annual adequacy assessment[15]
🇩🇰	✗	Not incorporated in adequacy assessment[16]
🇪🇸	✗	Mentioned as new mechanism - not incorporated in adequacy assessment[18]

* Experts claim this to be "beggars belief", which could mean that the increase in flexibility in France will be significantly smaller; Source: 1) DNV GL (2020); 2) Elia (2019, a); 3) Elia (2019, d); 4) DNV GL (2020, a); 5) Artelys (2019); 6) Magnus (2020); 7) E-CUBE (2020); 8) RTE (2019, a); 9) BloombergNEF (a); 10) Expert interview; 11) TenneT (2021); 12) Elia (2019, d); 13) BNetzA (2019); 14) BEIS (2020,b); 15) RTE (2019, b); 16) Energinet (2019, a); 17) Ministerio de IET (2015); Strategy& analysis

3

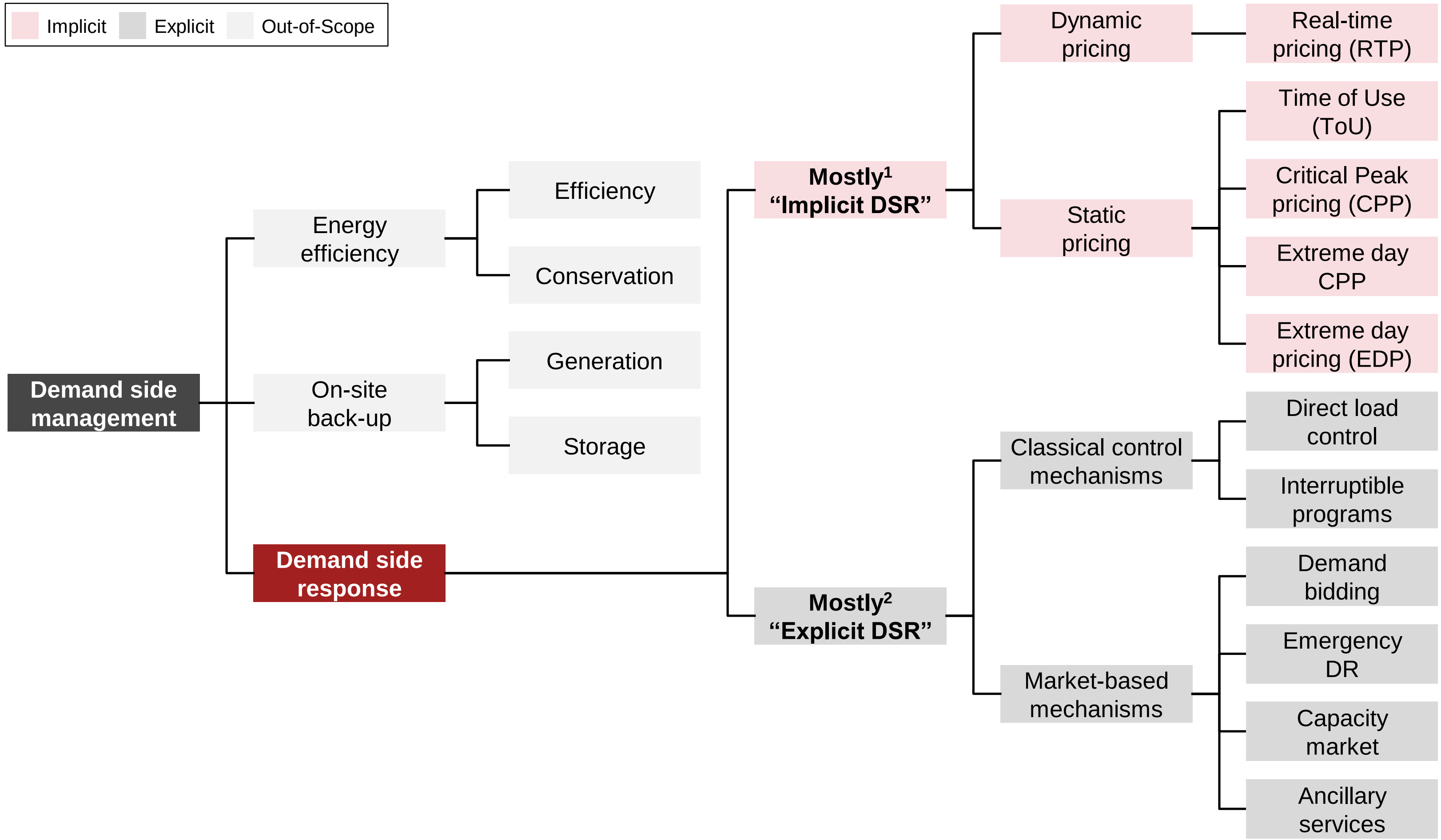
Industrial demand side response

Scope

Illustrative

This research focuses on both implicit (triggered by market prices) and explicit (triggered by control signal) DSR

Demand side management



🟥 Implicit ◼ Explicit ◻ Out-of-Scope

Demand side management	Energy efficiency	Efficiency			
		Conservation			
	On-site back-up	Generation			
		Storage			
	Demand side response	**Mostly[1] "Implicit DSR"**	Dynamic pricing	Real-time pricing (RTP)	Rates fluctuate to **reflect the real electricity cost** in the wholesale market and are communicated to customers on a **day-ahead** or **hour-ahead** basis
			Static pricing	Time of Use (ToU)	Different rates offered at different times of use (e.g. day and night) are used to incentivize consumers to **shift its consumption from peak to off-peak periods**
				Critical Peak pricing (CPP)	Rates include a **pre-specified higher usage price** superimposed on flat rates or ToU rates **if wholesale prices are high** or in case of **contingencies**
				Extreme day CPP	CPP rates for peak and off-peak periods are called **only during extreme days** and for the other days flat rates are used
				Extreme day pricing (EDP)	**Similar to CPP**, however higher usage price is **in effect for the full 24 hours** of the extreme day which is unknown until a day-ahead
		Mostly[2] "Explicit DSR"	Classical control mechanisms	Direct load control	Participant's **equipment** (e.g. processes at chemicals & air separation plants, paper & pulp industry etc.) **can be shut down** on short notice
				Interruptible programs	Participants receive **upfront incentive payments or rate discounts to reduce load to predefined levels** for a period of time, and incur penalties for non-compliance (not automatically activated, and typically less extreme conditions than, e.g. Emergency DR)
			Market-based mechanisms	Demand bidding	Participants **bid on specific load reductions in the wholesale market** and after acceptance of a bid the participant must oblige or incur penalties
				Emergency DR	Participants are paid incentives (often a **very high price** for a fast response) to **reduce load during emergency** conditions (e.g. to restore abrupt extreme frequency drops, typically automatically activated)
				Capacity market	Participants commit to **pre-specified load reductions amidst system contingencies** with, for example, a day's notice, with penalties for non-compliance, and get rewarded for both their availability and delivery
				Ancillary services	Participants **offer loads as operating reserves** in the **balancing & ancillary services markets** and receive a price for being available for (re)dispatch

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1) When not part of the initial energy supply contract, these pricing schemes can be agreed on explicitly, making it explicit DSR; 2) If these programs are embedded in the energy supply contract, and consumers can benefit from DSR by adjusting their consumption without being triggered by a control signal, this is regarded as implicit DSR

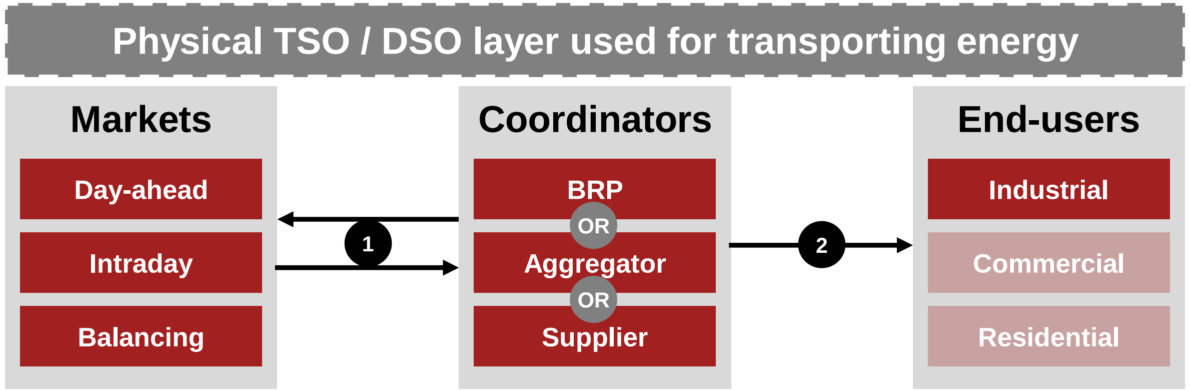
Source: Albadi and El-Saadany (2008); Warren (2014); Strategy& research

Implicit DSR is adjusting consumption triggered by price signal; explicit DSR is adjusting triggered by control signal

Implicit vs. explicit DSR

Implicit DSR

1. Buying / sourcing energy + portfolio balancing without flex
2. Dynamic pricing contract without explicit agreements on flex provisioning
3. End-user shifts / sheds consumption by themselves and benefits from lower prices at certain times



Physical TSO / DSO layer used for transporting energy

Markets

- Day-ahead
- Intraday
- Balancing

1

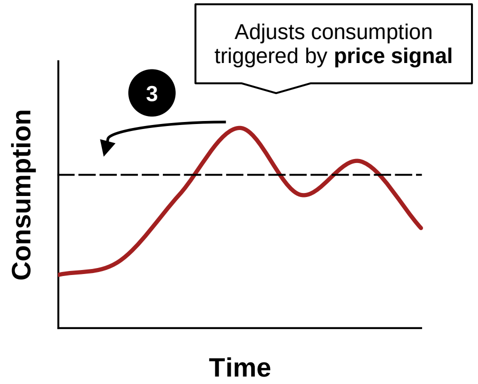
Coordinators

- BRP
- OR
- Aggregator
- OR
- Supplier

2

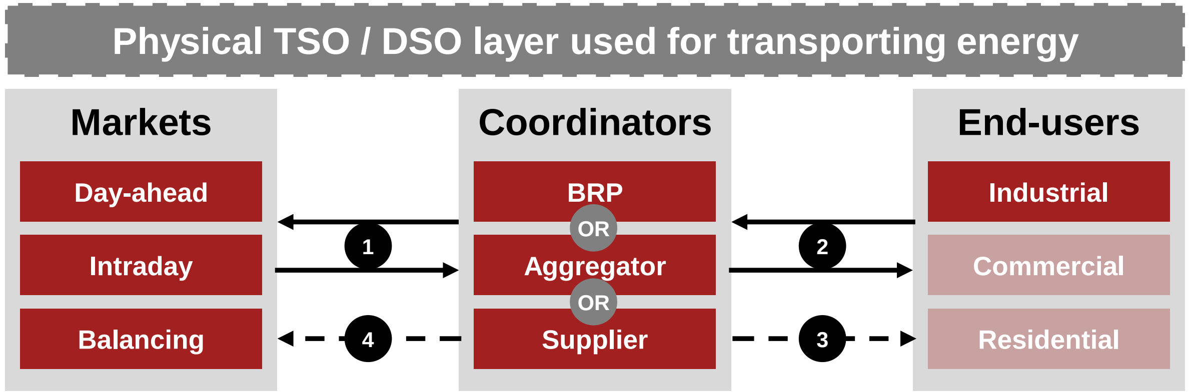
End-users

- Industrial
- Commercial
- Residential



Explicit DSR

1. Buying / sourcing energy + portfolio optimization with flex
2. Contract with normal supply conditions and flex related reimbursement
3. Control / deploy signals for flex activation and deactivation
4. Flex bids offered to the market
5. End-user shifts / sheds consumption based on signal



Physical TSO / DSO layer used for transporting energy

Markets

- Day-ahead
- Intraday
- Balancing

1

4

Coordinators

- BRP
- OR
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- OR
- Supplier

2

3

End-users

- Industrial
- Commercial
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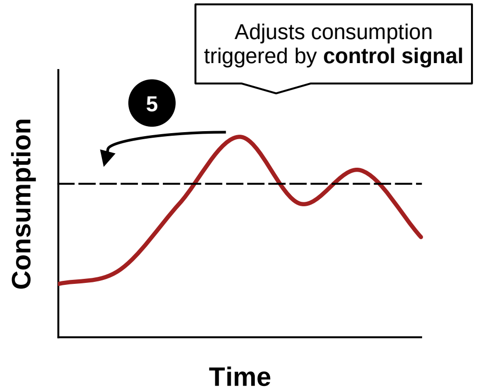

Source: Strategy& research

Illustrative

Market participants in DSR can be segmented into residential, commercial and industrial; this research focuses on the latter

Participants segmentation

Participant segment	Connection size[1]	Customer type	Technologies	DSR potential	DSR participation
Industrial	**Connection size** > 3x80 ampere **Peak capacity** > 0.1 MW	Industrial, large consumers (e.g. chemicals, food, metal, paper, glass, ceramics, oil, etc.)	Industrial processes	Shifting the load for electricity intense processes	Participation can be both **directly** as well as **through an aggregator**, depending on size of the consumed electricity volumes
			Power-to-heat	Generating and storing heat when electricity prices are low	
			Power-to-hydrogen	Electrolysis could be used to store electricity as hydrogen[3]	
Commercial	**Connection size** > 3x80 ampere **Peak capacity** > 0.1 MW	Commercial, large consumers, not being an industrial (e.g. corporates, hospitals, governmental organizations, etc.)	Power-to-heat	Generating and storing heat when electricity prices are low	Participation can be both **directly** as well as **through an aggregator**, depending on size of the consumed electricity volumes
			Electric vehicles	Increases generation potential of wind and solar PV (i.e. daytime)	
			Smart appliances	Shifting load of energy intensive appliances (e.g. refrigeration system)	
Residential	**Connection size** ≤ 3x80 ampere **Peak capacity** ≤ 0.1 MW	Small and medium-sized enterprises (SMEs)	Power-to-heat	Generating and storing heat when electricity prices are low	Participation in DSR programs so far always has to go **through an aggregator**, as participants consume too small electricity volumes[2]
		Households	Electric vehicles	Increases generation potential of mainly wind (i.e. nighttime)	
			Smart appliances	Using a smart grid to turn off/ on washing machines, dryers, etc.	

1) Based on Dutch regulation, may vary slightly between countries; 2) This might change in the future, e.g. with direct load mechanisms on residential level; 3) Only applies to largest industrials, as electrolysis plants are capital intensive

Source: IRENA (2019), p. 7; Strategy& research

Illustrative

We focus on mid-sized and large industrials, as they can provide the largest flex volumes, making them interesting for TSOs

Industrial DSR segmentation

Segment	Peak capacity[1]	Grid[1]	Customer profile	Metering[1)]	BRP	DSR Participation	Most relevant DSR programs		
Large	> 100 MW	TSO	Big industrials with **highly intense** electricity processes, often including own **generation**	Telemetric	Self-managed or Energy supplier	Direct or Aggregation	Direct load control Interruptible programs Demand bidding Emergency DR	Capacity market Ancillary services Real-time Pricing (RTP) Time of Use (ToU)	Critical Peak Pricing (CPP) Extreme day CPP Extreme day pricing (EDP)
Mid-sized	10 – 100 MW	DSO	Mid-sized industrials with **intense** electricity processes, often including own **generation**	Telemetric	Energy supplier	Direct or Aggregation	Direct load control Interruptible programs Demand bidding Emergency DR	Capacity market Ancillary services Real-time Pricing (RTP) Time of Use (ToU)	Critical Peak Pricing (CPP) Extreme day CPP Extreme day pricing (EDP)
Small	0.1 – 10 MW	DSO	Smaller industrials with **limited** electricity intense processes, **without own generation**	Telemetric	Energy supplier	Aggregation	Direct load control Interruptible programs Demand bidding Emergency DR	Capacity market Ancillary services Real-time Pricing (RTP) Time of Use (ToU)	Critical Peak Pricing (CPP) Extreme day CPP Extreme day pricing (EDP)

⬜ Explicit DSR 🟥 Implicit DSR

1) Based on Dutch situation, may vary slightly between countries
Source: Strategy& research

European electricity market is regulated by set of network codes, drafted by ENTSO-E and dictated by European Commission

EU regulation

Type	Code name	Abbreviation	Legislation
Connection	High Voltage Direct Current Connections	HVDCC	EU Regulation 2016/1447
	Requirements for Generators	RfG	EU Regulation 2016/631
	Demand Connection Code	**DCC**	**EU Regulation 2016/1388**
Operations	System Operations	SO	EU Regulation 2017/1485
	Emergency and Restoration	ER	EU Regulation 2017/2196
Market	Capacity Allocation & Congestion Management	CACM	EU Regulation 2015/1222
	Forward Capacity Allocation	FCA	EU Regulation 2016/1719
	Electricity Balancing	EB	EU Regulation 2017/2195

Demand side response

- **Harmonized requirements** for grid connection applicable to any new demand connection to the **transmission system**, any new demand equipment which could provide **DSR** and **distribution systems**
- **First EU legislation** to regulate Demand Side Response

Source: ENTSO-E; Strategy& research

Recently, *Clean Energy Package* was introduced to stimulate energy transition, which has significant implications for DSR

Clean energy package

EU Commission
"Clean energy for all Europeans package"

- Comprehensive update of **EU energy policy** to facilitate transition from fossil fuels to cleaner energy and deliver on Paris Agreement commitments
- **Topics covered:**
  - Energy performance buildings
  - Renewable energy
  - Energy efficiency
  - Governance & regulation
  - Electricity market design
- Legislative form:
  - **Regulation:** binding legal force in all member states
  - **Directive:** defined goals which have to be achieved through national legislation

Energy Performance of Buildings
Directive (2018/884)

The recast Renewable Energy
Directive (2018/2001)

The revised Energy Efficiency
Directive (2018/2002)

Governance of the Energy Union and Climate Action
Regulation (2018/1999)

Regulation of risk-preparedness in the electricity sector
Regulation (2019/941)

Regulation establishing EU ACER
Regulation (2019/942)

On the internal market for electricity
Regulation (2019/943)

On common rules for the internal market for electricity
Directive (2019/944)

Deep-dive on each legislation on next slides

Relevant for Demand Side Response

EU regulation 2019/943

- Sets basis for an **efficient achievement** of 2030 climate objectives
- Sets principles for well-functioning, integrated **wholesale market**
- Sets fair rules for **cross-border exchanges** in electricity

EU directive 2019/944

- Establishes integrated, competitive, flexible, fair and transparent **electricity markets**
- Aims to ensure affordable, transparent **energy prices** and a high degree of **security of supply**
- Sets out modes for the creation for a **fully interconnected internal market** for electricity

Source: European Commission (a); Strategy& research

Regulation has direct legal force in all member states; market access guaranteed for both implicit and explicit DSR

EU regulation 2019/943

Executive summary

- Customers should be enabled to act as a **market participant in the balancing, day-ahead and intraday** markets, either individually or through aggregation
- Market participants must either be **BRPs** or have **contractually delegated** their balance responsibility to a balancing responsible party of their choice
- **Tenders** for balancing capacity must be held **daily** and the contracting period shall be no longer than one day
- Settlement of balancing energy for activated balancing energy bids must be based on **pay-as-cleared**
- TSOs are obliged to **publish** system **imbalances**, **imbalance prices** and balancing energy prices, as close to real time as possible and with a delay of not more than 30 minutes
- Market participants should be able to **trade as close as possible to real-time** on the day-ahead and intraday markets, with **minimum bid sizes of 0.5 MW or less** and time intervals of max. **15 min (i.e. ISP)**
- **Transaction curtailment** by the DSO (e.g. blocking of demand side response programs) because of congestion management is only allowed in emergency situations
- **Network charges** shall not create disincentives for Demand Response and may be differentiated based on system users' consumption or generation profiles
- Member states must monitor their **resource adequacy** and, in case of any concerns, shall develop and publish an implementation plan for adopting measures to eliminate any regulatory distortions or market failures
- Introduction of **capacity mechanisms** to eliminate adequacy issues shall always be a measure of last resort, must be temporarily of nature and no longer than 10 years

Legislative status

- Published on June 5th 2019
- **Direct binding** legal force as of **January 1st 2020** in all member states
- **Overrides** all national laws dealing with the same subject matter and subsequent national legislation must be consistent with and made in the light of the regulation

Source: EU (2019/943); Strategy& research

Directive has to be implemented in national law; dynamic pricing, smart metering and 3rd party aggregation obligated

EU directive 2019/944

Executive summary

- National law may **not unduly hamper consumer participation through Demand Response**, and shall ensure that electricity prices reflect actual demand and supply
- **Free choice of energy supplier** and **multiple supplier contracts** are allowed, provided that the required connection and metering points are established
- Member states shall make sure that **storage facilities are not subject to any double charges**, including network charges, when these are for own use or to provide flexibility into the market
- **Dynamic pricing contracts** should be available upon request for customers who have a smart meter and with suppliers that have at least 200,000 final customers
- **Independent aggregation** shall be made possible, so that consumers can choose an aggregation contract independently from their electricity supply contract without the consent of the energy supplier and independent aggregators can enter the electricity market without consent of other market participants
- **Smart metering systems** shall provide near real-time data in order to support Demand Response services and shall be metered and settled at the ISP (i.e. 15 min); moreover, they should always be available upon request by customer, while bearing the associated costs, and shall be installed within four months of this request
- Ancillary services, procured by TSOs and DSOs, shall be made available for demand side response by setting the **specifications** (e.g. technical requirements) for these balancing products in such a way as to ensure transparent, effective, non-discriminatory and market-based participation

Legislative status

- Published on June 5th 2019
- **Must be implemented** in national law as of **December 31st 2019** for vast majority of the articles, with remainder following one year later
- Adopted by all member states in scope (**Netherlands, Germany, Belgium, France, Spain and Denmark**)
- While **Great Britain** not being a member state anymore, they adopted the directive[1]
- **Non-compliance** may initiate legal action against the member state in the European Court of Justice
- In addition, non-compliance can cause **liability to pay damages** to individuals and companies who have been adversely affected by such non-implementation

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[1] Ofgem claims the directive was implemented as of December 31, 2020

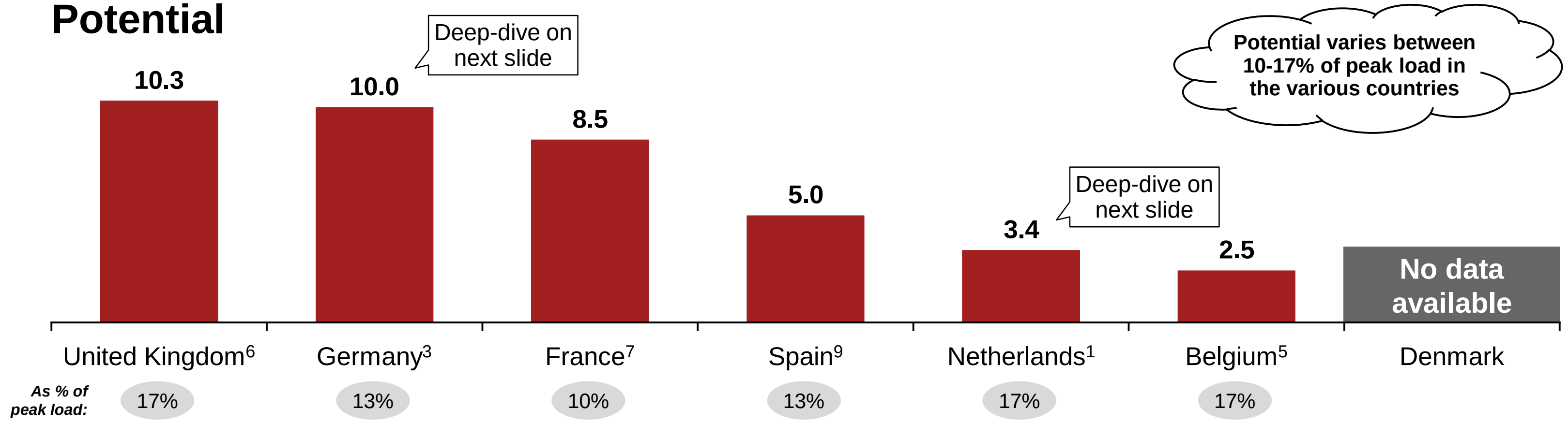
Source: EU (2019/944); Strategy& research

Industrial DSR potential varies by country (10-17% of peak load) and actual participation illustrates its importance

Current industrial DSR potential and participation *(2020, in GW)*

INDICATIVE

Potential



Participation

6.3	**3.0**[i]	**5.0**	**2.0**	**0.7 - 2.0**	**1.4**	**No data available**
Source						
Pöyry (2017)	Valdes et al. (2019)	DNV GL (2020, a)	Magnus (2020)	TenneT (2019)	Elia (2019)	
Methodology						
Participation rates not measured, but estimated based on a bottom-up model with assumptions on DSR participation by source over time	Taking the sum of prequalified DSR capacity in the balancing market in a given year	Underlying methodology remains unclear, however it states that both explicit and implicit DSR is taking into account	Taking the sum of the capacity tenders for the interruptible load programs in a given year	Based on a day-ahead bid ladder analysis with a 95% - 5% percentile range of available capacity, excluding DSR in balancing market	Based on both a day-ahead bid ladder analysis and adding up tendered DSR capacity in the balancing market	

Comments

- There is an important difference between **economical** and **technical DSR potential**, with the latter showing the maximum capacity flex an industrial can offer, whereas the former shows the capacity an industrial is willing to offer based on the market conditions; it **was not always clear** which metric was stated in the used resources
- Potential DSR figures shown are therefore **purely indicative**, as some of the results might be overstated
- Nevertheless, it is clear that **industrial DSR potential varies by country** (between 10-17% of peak load), depending on their size of industrial electricity consumption and sectoral representation of industries that are likely to participate in DSR
- **Methodologies** underlying the measurement of industrial DSR participation rates **vary significantly** by country, making a direct like-for-like comparison impossible
- However, the figures shown clearly indicate the **substantial gap** between current participation rates and industrial DSR potential across all countries in scope

i) TenneT internal sources indicate 1.0-1.5 GW industrial participation through the interruptible load program

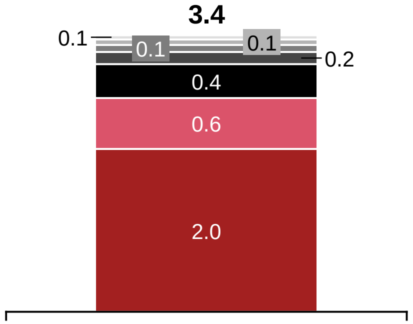
Source: 1) DNV GL (2020); 2) Valdes et al. (2019); 3) Dena (a); 4) Elia (2019, d); 5) Febeliec (2013), extrapolated results from survey based on relative percentage electricity consumption of industrials that participated; 6) Pöyry (2017); 7) uFE (a) 8) DNV GL (2020, a); 9) Sia Partners (2014); 10) Magnus (2020); Strategy& analysis

Indicative

Potential DSR capacity varies by industry, depending on production criteria, dictating a country's full potential

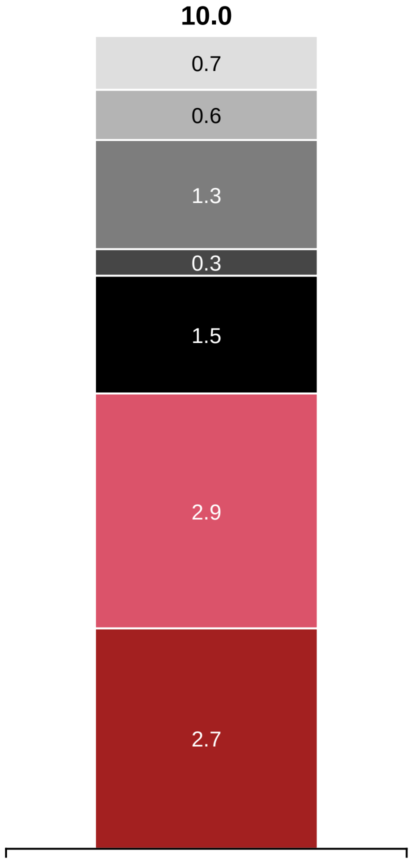
Deep-dive: Netherlands (NL) and Germany (DE)[ii]

Potential DSR capacity by industry in NL[i] *(2020, in GW)*



⬜	**Glass**	Shedding production or lowering oven temperature (1 hour to 3 weeks), incremental activation
▨	**Ceramics**	Shedding of production (1 to 3 weeks), incremental activation
▨	**Paper**	Shifting production batch (1-24 hours) or shedding production (up to 3 weeks), incremental activation
⬛	**Oil refineries**	Shedding of production for at least 3 weeks, incremental activation
⬛	**Food**	Shedding production (1-24 hours) or lowering load continuous process (up to 3 weeks), incremental activation
🟥	**Metal**	Shedding production (1 to 3 weeks for iron/steel; 1 hour to 3 weeks for non-ferrous metals), binary activation
🟥	**Chemicals**	Shifting production batch (24 hour to 3 weeks), shedding production (6 hour to 3 weeks), incremental activation

Potential DSR capacity by industry in DE[i] *(2020, in GW)*



⬜	**Glass**	Shedding production or lowering oven temperature (1 hour to 3 weeks), incremental activation
▨	**Auto-motive**	Load shifting by using variation in cycle time of production line machines
▨	**Paper**	Shifting production batch (1-24 hours) or shedding production (up to 3 weeks), incremental activation
⬛	**Machinery**	Load shifting by using variation in cycle time of production line machines
⬛	**Plastics**	Shedding production or lowering oven temperature (1 hour to 3 weeks), incremental activation
🟥	**Steel**	Shedding production (1 to 3 weeks) binary activation
🟥	**Chemicals**	Shifting production batch (24 hour to 3 weeks), shedding production (6 hour to 3 weeks), incremental activation

i) Numbers are based on economical iDSR potential; ii) Similar figures from the other countries in scope were not available
Source: DNV GL (2020); BNetzA (2019); FED (a); Strategy& analysis

4

Guiding principles and observations across countries

We used the following research framework to categorize our observations, which led to four guiding principles per axis

Research framework and methodology

Market access

Do industrials have, directly or indirectly, access to the relevant electricity markets, so they are adequately enabled to participate in both implicit and explicit DSR?

Economic attractiveness

Are markets providing the right incentives to industrials to participate in DSR and do they enable them to build an attractive business case around this?

Market participation

Are markets designed in such a way that they maximize participation in DSR, by removing potential barriers and adapting to the preferences of industrials?

Operations and enforcement

Do operations and enforcement fully enable and facilitate industrial DSR, by providing the right tools and incentives?

See next slides for a deep-dive on the guiding principles per axis

Operations and enforcement

Market participation

Economic attractiveness

Market access

- Wholesale markets are accessible…
- Balancing markets are open…
- Industrials are exposed to…
- Industrials should be able to choose…

Methodology

- We used **desk research** and **expert interviews** (with TSOs, NRAs, industrials, aggregators, and stakeholder organizations) to gather **measures**, **mechanisms** and **policies** that impacted the unlocking of iDSR in seven European countries: the Netherlands, Germany, Belgium, United Kingdom, France, Denmark and Spain
- Along **four different axes** (market access, economic attractiveness, market participation, operations and enforcement), we identified the **observations** from the different countries and synthesized these into **four guiding principles per axis**
- These guiding principles **need to be in place to fully unlock iDSR** potential in a given country, which is further elaborated on (e.g. why is it important and how can this be realized) in the remainder of this section

Source: Strategy& research

Full access requires markets to accept and embrace DSR, industrials' exposure to prices, and independent aggregation

Market access

	Guiding principles		Observations
i.	***Wholesale markets*** *(day-ahead, intraday) are accessible for industrials*	• In order to valorize flexible capacity, it should be possible to trade this flex on the wholesale market, either directly or indirectly • Therefore, customers should be allowed, both legally and by market design (e.g. minimum bid sizes), to trade electricity on the day-ahead and intraday markets either directly or indirectly (e.g. through aggregation)	• Although access to wholesale markets is guaranteed (conform the CEP[9]) in most of the countries in scope, we have observed some deviations • In Belgium, market access is reserved for BRPs, other market participants require a "pass through" agreement, although this is typically part of an energy supply contract by default, according to Elia[2,7] • In Spain, the wholesale market is not accessible for industrials[7]
ii.	***Balancing capacity and energy markets*** *are open to DSR both legally and by product design*	• In order to participate in explicit DSR through the balancing market (both energy as well as capacity, if applicable), balancing products have to allow DSR both explicitly as well as implicitly by their product design (e.g. symmetry requirements) • Therefore, there should be a number of balancing products, from different balancing reserve classes, accessible to symmetrical load which ensures a level playing field for DSR to participate in this market	• Across Europe, two groups can be distinguished: (i) countries with a wide range of different balancing products, tailored around the specific needs of specific technologies, such as DSR (e.g. GB[5], FR[5,6]); and (ii) countries with a limited range of generic balancing products that are technology agnostic (e.g. NL, BE, DE, and DK)[6] • Spain had only one product opened to DSR: the interruptible load program, which is shut down in the peninsular system as of June 2020. Since January 2021, demand facilities are able to participate in all balancing markets through their energy supplier[1,7]
iii.	*Industrials are* ***exposed*** *to, and get* ***information*** *on,* ***electricity market prices***	• Dynamic pricing contracts and near real-time pricing information are needed for industrials to be exposed to electricity market prices and to be able of valorizing their flexible capacity through implicit DSR • Therefore, energy suppliers should be obligated to allow for dynamic pricing (e.g. real-time pricing, time of use) in their contracts with customers and should actively share pricing near real-time pricing information, derived from the wholesale / balancing markets	• Based on the CEP, dynamic pricing contracts should be available upon request for customers who have a smart meter and with suppliers that serve at least 200k final customers[8] • Across Europe, this seems to be implemented with all countries in scope obligating the suppliers to offer some kind of dynamic pricing in the energy supply contracts • United Kingdom[4] and Denmark[3] have specified the type of dynamic contracts that need to be available, with 'Time of Use' and 'Real-Time' pricing, respectively
iv.	*Industrials should be able to* ***choose an aggregator*** *of their choice, independently from their energy supply contract*	• Independent aggregators are typically more specialized in offering aggregation services than BRPs offering these services, and can significantly improve the functioning of the market – especially in countries with a limited number of electricity suppliers • Therefore, regulation should allow for independent aggregation such that they can participate in the market without consent of the other participants	• While conflicting with the CEP, in the majority of the countries in scope, except for GB[7], FR[6] and Belgium, independent aggregation is hindered due to: (i) the obligation for aggregators to have multiple bilateral contracts with the BRP, energy supplier, and industrial; and / or (ii) required consent of the energy supplier • Belgium[1,2,6,7] and France[1,2,6,7] have introduced a 'Transfer of Energy' model, which enables independent aggregation as consent of the energy supplier is no longer required and transfer of information (e.g. metering data) is arranged by law • Spain is planning to allow for participation through independent aggregation as of January 2022[1]

Source: 1) Expert interview; 2) Pentalateral Forum (2017); 3) Schultz et al. (2016); 4) DNV GL (2020); 5) smartEn (2020, a); 6) SEDC (2017); 7) JCR (2016); 8) EU 2019/944; 9) EU (2019/943); Strategy& research

There should be no financial disincentives, clear and timely published (price) information and a fair pricing mechanism

Economic attractiveness

	Guiding principles		Observations
i.	*There should be* ***no financial disincentives*** *for DSR participation*	- Financial disincentive that reduce the financial benefits from participating in DSR, can potentially limit its economic attractiveness and thus willingness to participate among industrials - Therefore, any significant financial disincentives for participating in DSR (e.g. discounts on network tariffs, in case of flat consumption) should be removed	- Based on the CEP, network charges shall not create financial disincentives for consumers to participate in DSR (e.g. discounts or premiums in case of stable or fluctuating consumption)[13] - However, Netherlands[5,6] and Germany[3,4] both have discounts on network tariffs (up to 90% and 50%, respectively), in case of a stable consumption pattern, which constitutes a significant disincentive for participating in DSR
ii.	*Balancing market is designed to* ***minimize cost of procurement*** *and* ***maximize*** *the sum of* ***producer surplus***	- The cost of balancing procurement should be minimized (as costs are eventually passed on in network tariffs) and producer surplus (i.e. surplus for industrial) should be maximized, by ensuring that TSOs pay fair prices to industrials, which improves their business case and increases their willingness to participate in DSR - To boost DSR participation while minimizing procurement costs, tender participants should be protected against their irrational behavior (i.e. “bidding to get taken”), which could result from ‘Pay-as-Bid’ mechanism	- Based on the EBGL and confirmed with the CEP, settlement of the activated energy in the balancing market shall be based on ‘Pay-as-Cleared’ pricing[13,15], although we have not seen that successfully implemented in all member states - Netherlands has introduced ‘Pay-as-Cleared’ (i.e. highest price for which the tender can be settled) settlement pricing for the vast majority of its balancing products[7,8,9] - Germany has a ‘Pay-as-Cleared’ mechanism for FCR, whereas ‘Pay-as-Bid’ mechanisms are used for aFRR and mFRR for both the balancing capacity and energy markets[1,10]
iii.	*All relevant* ***information*** *of the balancing market is* ***readily available*** *and* ***timely published***	- In order to build a solid business case and to optimally benefit from fluctuating market prices, a reliable and timely information provision is essential for industrials - Therefore, imbalance volumes, prices, and forecasts need to be published by the TSO as close as real-time as possible	- Based on the CEP, TSOs are obliged to publish system imbalances, imbalance prices and balancing energy prices, as close as real-time as possible and with a delay of not more than 30 minutes[13] - Netherlands[11], Germany[10] and United Kingdom[2] have a dedicated platform where imbalance volumes, prices and forecasts are published. The Netherlands especially, is renowned about its clear and timely (near real-time) pricing signals, enabling passive balancing, which offers industrials the opportunity to benefit from solving market imbalances with an opposed imbalance in its own portfolio[1,12] - The information provision around the balancing market in France is regarded as weak[1]
iv.	*Final electricity prices are* ***not unduly distorted*** *to ensure the signaling function to the market*	- Industrials tend to assess business opportunities on a percentage difference basis, so when the electricity price is only a marginal portion of the final price, percent differences in that price translate into lower percent differences in the final price, limiting the signaling effect of the wholesale and imbalance prices - Therefore, final electricity prices shall not unduly be distorted with excessive network tariffs, taxes and other fees	- In Germany, prices are heavily distorted, due to relatively large share of the final electricity price consists of taxes and network tariffs (~83% of energy price, relatively to ~44% in other EU countries), which limits the signaling function of the wholesale and imbalance prices[1,3,4,12,13] - Relevant to mention that price distortion varies by consumer profile. Due to discounts and exceptions, the network costs and taxes of medium and large industrials will be relatively low in comparison with smaller consumers. In the Netherlands, France and Belgium, the electricity bill for large industrial consumers consists almost entirely of the wholesale price, making the price incentive strong. In Germany, however, the tax rate remains relatively high (~50%), consequently the price distortion is still significantly higher[14]

Source: 1) Expert interview; 2) NGESO (b); 3) Clean Energy Wire (2017); 4) Clean Energy Wire (2019, b); 5) ACM (2020); 6) Kamerstukken II 2013/2014, 33777, nr. 3 (MvT); 7) TenneT (2020, b); 8) TenneT (2019, c); 9) TenneT (2018, a); 10) Regelleistung (a); 11) TenneT (b); 12) SEDC (2017); 13) EU 2019/943; 14) PwC (2018, a); 15) EU 2017/2195

Industrials must be fully aware of the opportunities DSR could offer, and markets should be designed to optimize participation

Market participation

	Guiding principles		Observations
i.	*Industrials are **fully aware** of how to participate in, and benefit from, DSR*	• In a climate neutral power system, flexible power consumption will be the norm. Industrials must be aware of the possibilities and benefits of DSR and its importance for the future of the energy system • Industrials should have easy access to clear information on how to participate, and what the precondition and economic benefits are associated with this (this is regarded as "fully aware")[14]	• In many countries unawareness among industrials is a barrier to large-scale participation.[1] Industrials indicate a need for decent information channels with dedicated go-to persons, who actively approach industrials to stimulate DSR participation[1,15] • GB's National Grid set up (investing 3 FTE) a stakeholder led program "Power Responsive", to increase awareness and improve the information provision. They organize conferences and regular meetings with relevant stakeholders to discuss issues and find solutions.[1,4] To alleviate industrials' concerns around disrupting their core business, campaigns with case studies are provided.[1] In France, there are regular meetings (every 6 weeks) between RTE and market participants for public consultation on regulation[1]
ii.	*There is a strong presence of **mature aggregators** in the market*	• Participating in DSR is not the core business of industrials. Even for large players, the market is deemed complex, with a broad spectrum of products, and a variety of technical rules and protocols • Aggregators' core competence is pooling flexible capacity and trading this on the market. Therefore, they should play a crucial role for industrials in helping them to unlock their flexible capacity, provided that they are knowledgeable and regarded a trustworthy partner by industrials[16,17]	• In most countries, industrials participate primarily through aggregators (e.g. in France >95%), except for the largest players. Reasons are the complexity of market, the lack of expertise on tenders and trading, the ever changing regulation and the administrative burden[1] • In Great Britain, the Association of Decentralized Energy introduced "Flex Assure".[1, 18] This is a Code of Conduct scheme, which was developed by industry to set industry standards and best practices for aggregators providing aggregation services to businesses.[1] It's an independent stamp of approval, which aggregators apply for on a voluntary basis, and proved to enhance uniformization significantly[1]
iii.	*Balancing capacity and energy **product requirements must be well designed** to optimize DSR participation*	• Industrials differ in electricity volumes, availability and flexibility (due to utilization differences), that do not always fit to the balancing product specifications, constituting a (potential) barrier to participate in DSR • Therefore, balancing products (both energy and, if applicable, capacity products) should be well designed, so that they do not constitute an (implicit) barrier to DSR participation for (some of the) industrials, e.g. regarding the minimal bid size (not too high) or response time (not too fast), which is also stipulated in the CEP[13,16,19]	• While most countries have low minimum bid sizes (e.g. the Netherlands, Germany, France, Great Britain - max. 1.0 MW in general)[2,3], there are some exceptions (e.g. Denmark[5] 10 MW in tertiary reserve and Netherlands[3,7] 20 MW for mFRRda[i]) which is not in line with CEP (i.e. minimum bid size of 0.5 MW)[19] • In Denmark, the short response time (e.g. 5-25 sec in primary reserve) is seen by industrials as a barrier to participate.[5] In Great Britain some of the fast-acting services cannot be participated by DSR[1] • France organizes annually a "DR Call for Tenders", with better pricing conditions to reach their DSR target of 6.5 GW by 2028.[1,2,3] Furthermore, their capacity mechanism boosts DSR participation, by obligating energy suppliers to provide capacity guarantees to cover peak loads through demand side response[1,2,3]
iv.	*Balancing market allows for **optimal planning flexibility** for industrials*	• Industrial processes can be unpredictable due to shocks in supply or demand, unplanned maintenance, or other factors impacting the supply chain, which stresses the need for industrials to remain fully flexible in their electricity procurement • Therefore, balancing tenders should be organized in such a way to allow for optimal planning flexibility for industrials by leaving them the opportunity to trade in flexible capacity as close to real-time as possible	• Countries are shifting closer to real-time in their balancing tenders. Great Britain is shifting from month-ahead tenders to weekly auctions, to be more aligned with DSR providers' needs.[1,6] France is moving from monthly to weekly tenders, to better facilitate aggregation pools[1] • In Germany[10] and the Netherlands[8,9], balancing tenders take place on a daily basis (conform CEP)[19] • Alternatively to shifting closer to real-time, TSOs could also facilitate secondary markets to realize optimal planning flexibility for industrials (i.e. as they have the opportunity sell their earlier tendered flex to other parties, in case they need the capacity for their own production) like Elia did in Belgium[11,12]

i) mFRRda is still manually activated (e.g. in NL by control signal), which justifies the relatively high threshold; Source: 1) Expert interview; 2) smartEn (2020, a); 3) SEDC (2017); 4) National Grid (2017, a); 5) JCR (2016); 6) DNV GL (2020); 7) TenneT (2019, b); 8) TenneT (2020, b); 9) TenneT (2019, c); 10) Regelleistung (a); 11) Elia (2020, b); 12) Elia (2020, c); 13) Barbero et al. (2020); 14) Cardosa et al. (2020); 15) Heffner et al. (2007); 16) Paterakis et al. (2017); 17) Shen et al. (2014); 18) Flex Assure (a); 19) EU 2019/943

Metering requirements, compliance enforcement, and pre-qualification methods should not unduly hinder DSR

Operations and enforcement

	Guiding principles		Observations
i.	***Telemetric / smart metering*** *are available and can be used in the settlement process*	• In order to be able to valorize flexible capacity, industrials need to know their actual consumption levels, which should be frequently communicated, so they can be used in the settlement process – which can be done though telemetric / smart metering systems • Therefore, telemetric / smart metering should be available upon request, provide near real-time consumption data, so it can be used to settle against the ISP (i.e. 15 min)	• Based on the CEP, smart metering systems should be available upon request, provide near real-time metering data, and can be used to settle against the ISP[6] • In most countries in scope, we observed efforts in this regard. In Belgium[8], the Netherlands[7] and Great Britain[2], large connections (typically +0.1 MW) are obliged by law to have telemetric metering systems. In France[3], all parties connected to the transmission network receive a meter from the TSO. In Denmark[4], a smart meter rollout is fully implemented in 2020 for all consumers, including industrials
ii.	***Submeters'*** *criteria for settlement process are not unduly strict*	• Industrials typically have a variety of assets, with different specifics (i.e. volumes, availability and flexibility), active on the same main grid connection. To optimally valorize the flexible capacity from these assets, their consumption levels should be measured and settled in isolation[10] • Therefore, metering requirements should not be unduly strict, so that submeters can be used in the settlement process	• Metering requirements tend to be quite strict, to prevent non-accountability for causing imbalances which have to be resolved by the TSO on the balancing market on its own expense • However, in several interviews with aggregators, we heard back that metering requirements in Netherlands, Belgium, and Germany are so strict that practically no submeters can be used in the settlement process, limiting the opportunities for aggregation and thus unlocking of flexible capacity[1]
iii.	***Compliance with agreements*** *should be enforced through regulations and reasonable penalties*	• A balanced network needs reliable market players, who comply with their contracts and agreements, such as delivering contracted flexible capacity upon request and fulfilling the pre-qualification requirements during regularly audits • Therefore, regulations should provide the right incentives to industrials to comply with their contracts and agreements, such as reasonable penalties	• In Netherlands[9] and Belgium[9] the penalties are proportional to the costs incurred by the TSO to solve the imbalances, resulting from non-compliance, which is deemed reasonable by market players • In France, high competition among aggregators led to bad contracts (i.e. very low margins), making the aggregation services unreliable. As a result, RTE initiated strict rules which remedied these reliability issues[1]
iv.	***Pre-qualification method*** *shall not be unduly strict*	• To fully unlock DSR potential, all assets that can provide flexible capacity need to be able to do so. Pre-qualification methods can limit the participation of individual assets that do not fulfil the requirements, while they could have participated in a pooled setting • Therefore, pre-qualification methods for the balancing market shall not be unduly strict to allow for pooling of individual assets	• In the Netherlands, Germany and Denmark, pre-qualification for most of the balancing products is allowed at the pooled level[5,9]

Source: 1) Expert interview; 2) Ofgem (2016); 3) Pentalateral Forum (2017); 4) Schultz et al. (2016); 5) JCR (2016); 6) EU (2019/944); 7) Netcode Elektriciteit (2020); 8) FOD Energie (2019); 9) SEDC (2017); 10) Behrangrad (2015); Strategy& research

Two additional trends regarding DSR are observed in various countries

Additional observations

TSOs accelerating investments in IT

Market participants, including the TSO, are increasingly dependent on IT systems for communication and data provision in a changing energy market and a larger multi-stakeholder playing field. Especially regarding DSR development, a well-functioning data provision is essential, e.g. (near) real-time communication and smart metering. This requires new capabilities and therefore continued investing in digitalization. In various countries in scope, these efforts are observed

In Denmark, the electricity market used the DataHub since 2013.[1] The DataHub facilitates and automates the execution of market processes and business transactions in the Danish retail market by storing every piece of information about the electricity consumption in DataHub. The overall purpose of the transformation is to stimulate competition, uniformize communication, encourage innovation and to motivate the demand-side of the market to play an active role in Denmark's green transition. Currently, the DataHub has no impact on DSR, but in the future, the TSO could potentially use the DataHub to virtually control DSR activation

In Great Britain, National Grid acknowledges the investment is necessary to continue facilitating developments in the market, including DSR. The plans of digitization are currently being developed[2]

TenneT also sees opportunities in the field of digitalization to improve the utilization of the grid. In this regard, they are for example, exploring the potential of big data to improve their capacity to predict the weather and assess levels of consumer demand. TenneT continuously develops its IT capabilities, enhancing its organization, training employees and reviewing the performance of IT service providers[3]

DSOs increasingly play a role in DSR

DSOs will increasingly play a role in the DSR market, due to increased decentralized generation (RES) and significant number of EV charging points newly connected to the grid in the coming years. These trends will put pressure on the distribution networks and increase the risk of congestion issues. Therefore, DSOs are expected to monitor DSR participation on the grid closely and might even leverage the technology in their own congestion management efforts

In Germany, DSOs theoretically have to approve the DSR participation in the balancing market in order to prevent congestion issues. This potentially delays the opportunity to participate in DSR[2]

Likewise in Belgium, DSOs are allowed to block or refuse consumer access to DSR participation to prevent potential congestion, without reimbursing incurred costs

In Great Britain, DSOs start to develop DSR services. The pressure on DSOs increases, as the network load rises but the TOTEX regulation steers on deferring of network investment and expansion.[2] To realize the needed load reduction, DSOs start to develop flexibility services to procure DSR flexibility. In this manner, DSOs are interested in DSR as "non-wired solution"[2]

Source: 1) Energinet (a); 2) Expert interview; 3) TenneT (2020, c); Strategy& research

5

Key learnings

We identified several guiding principles along four dimensions that can help in fully unlocking industrial DSR potential

Guiding principles

Market access	Economic attractiveness	Market participation	Operations & enforcement
i. **Wholesale markets** (day-ahead, intraday) are accessible for industrials	i. There should be **no financial disincentives** for DSR participation	i. Industrials are **fully aware** of how to participate in, and benefit from, DSR	i. **Telemetric / smart metering** are available and can be used in the settlement process
ii. **Balancing capacity and energy markets** are open to DSR both legally and by product design	ii. Balancing market is designed to **minimize cost of procurement** and **maximize** the sum of **producer surplus**	ii. There is a strong presence of **mature aggregators** in the market	ii. (**Sub)metering** criteria for settlement process are not unduly strict
iii. Industrials are **exposed** to, and get **information** on, **electricity market prices**	iii. All relevant **information** of the balancing market is **readily available** and **timely published**	iii. Balancing capacity and energy **product requirements** must be **well designed** to optimize DSR participation	iii. **Compliance with agreements** should be enforced through regulations and reasonable penalties
iv. Industrials should be able to **choose an aggregator** of their choice, independently from their energy supply contract	iv. Final electricity prices are **not unduly distorted** to ensure the signaling function to the market	iv. Balancing market allows for **optimal planning flexibility** for industrials	iv. **Pre-qualification method** shall not be unduly strict

The guiding principles are derived from our observations resulting from studying the seven countries in scope and assessing their importance for unlocking iDSR potential. However, the principles depend on the context of the individual countries and do not guarantee a successful unlocking of industrial DSR. Shown assessment on guiding principles on the next two slides is therefore not intended as ranking, but rather as indication for whether the country deviates from our identified principles. In addition, we have provided context on the (potential) rationale behind these deviations.

Source: Strategy& research

NL could consider to facilitate independent aggregation even more, remove financial disincentives, and stimulate awareness

Guiding principles applied on the Netherlands

Legend: ✓ No deviation from guiding principle ~ Light deviation ✗ Strong deviation

	Market access		Economic attractiveness		Market participation		Operations & enforcement	
Alignment with guiding principles	✓	Accessible wholesale markets	✗	No financial disincentives	✗	Full awareness	✓	Telemetric / smart metering available
	✓	Open balancing products	✓	Maximized consumer and producer surplus	~	Presence of mature aggregators	✗	(Sub)metering criteria are not unduly strict
	✓	Exposure to electricity market prices	✓	Information is readily and timely available	✓	Well-designed balancing products	✓	Compliance with agreements
	~	Enabling independent aggregation	✓	Electricity prices not unduly distorted	✓	Optimal planning flexibility	✓	Pre-qualification not unduly strict
Context of deviations		• Based on current Dutch regulation, large connections (i.e. above ~0.1 MW) and thus industrials do have the ability to become a BRP. In this capacity they can make own agreements with an (independent) aggregator of their choice[8] • However, access to metering data is not regulated by law, which potentially constitutes a barrier to independent aggregators, as they rely on the cooperation of the energy supplier / metering company / BRP[1,8] • The new draft legislation 'Energiewet' (partly) mitigates this barrier, as it obligates energy suppliers to provide access to metering data against a 'reasonable offer'[9] • The conditions under which access to metering data must be provided, are planned to be detailed out through lower regulation at a later stage.[9] To fully enable independent aggregation it is important that this access is not unduly hindered which could hinder independent aggregation		• In order to optimize DSR participation, it is important to limit (potential) financial disincentives as much as possible • The network charge discount, available to large electricity consumers in case of a stable consumption pattern, helps TenneT in their congestion management efforts • However, this discount can unconsciously disincentivize industrials to participate in DSR.[2,3] As participation in DSR implies a more fluctuating electricity consumption, industrials risk losing this discount		• To fully unlock DSR participation, it is essential that industrials are aware about how they can participate and benefit from offering their flexible capacity into the electricity market[1,4] • This awareness in the Netherlands is relatively weak, which can be potentially explained by the lack of initiatives to actively involve and inform the various stakeholders on DSR. An example initiative is to organize a central stakeholder participation program where industrials can collaborate and share information on barriers they are facing.[1,5,10] Furthermore, frequent and adequate reporting on DSR can contribute to raising awareness, which can be realized through annual reports, surveys and easily accessible informative websites[1,6] • Aggregators also play a crucial role in the transfer of information to industrials regarding DSR. Therefore, it is important to ensure the presence of knowledgeable and mature aggregators in a country, which can be realized by certification or a general code of conduct[1,6]		• To realize an optimal participation in DSR with the different assets an industrial might have, it is important to measure their electricity consumption in isolation. Therefore it is important that submetering systems can be used in the settlement process[1] • Metering criteria in the Netherlands are quite strict to ensure reliable and accurate measurements to prevent non-accountability for caused imbalances by end-users, which TenneT has to resolve and incurs costs for • However, these metering criteria could be unduly strict, resulting in submeters to not qualify for the settlement process whereas they proved to be a reliable tool for aggregators[1]

Source: 1) Expert interview; 2) ACM (2020); 3) Kamerstukken II 2013/2014, 33777, nr. 3 (MvT); 4) Heffner et al. (2007); 5) National Grid (2017, a); 6) Flex Assure (a); 7) Behrangrad (2015); 8) ACM (2019); 9) Energiewet (2020); 10) NGESO (2019, a) Strategy& research

On top of the Dutch considerations, Germany could consider to open all balancing products and reduce price distortion

Guiding principles applied on Germany

Legend: ✓ No deviation from guiding principle ~ Light deviation ✗ Strong deviation

	Market access		Economic attractiveness		Market participation		Operations & enforcement	
Alignment with guiding principles	✓	Accessible wholesale markets	✗	No financial disincentives	✗	Full awareness	✓	Telemetric / smart metering available
	~	Open balancing products	~	Maximized consumer and producer surplus	~	Presence of mature aggregators	✗	(Sub)metering criteria are not unduly strict
	✓	Exposure to electricity market prices	✓	Information is readily and timely available	✓	Well-designed balancing products	✓	Compliance with agreements
	~	Enabling independent aggregation	✗	Electricity prices not unduly distorted	✓	Optimal planning flexibility	✓	Pre-qualification not unduly strict
Context of deviations	• In Germany, a number of balancing capacity and energy markets are closed for Demand Side Response, either because legislation does not allow DSR (e.g. winter reserve product), or by being implicitly not accessible due to the product design (e.g. for the product ”capacity reserve”[i]).[5,6,7] This may be unduly hindering market access and therefore the rationale behind this blocking should be considered carefully • In the basis, independent aggregation is enabled in Germany. However, due to the requirement for the aggregator to have a multitude of different contracts with the industrial, BRP and energy supplier, independent aggregation is significantly hindered.[1,4,5,6,7] It remains unclear whether this barrier will be mitigated by future regulation, in order to be (more) compliant with the CEP – like the Netherlands is currently pursuiting[1]		• See context of deviations regarding financial disincentives of NL on the previous slide[2,3] • Pay-as-Bid is commonly used in the tendering of balancing products, which guarantees theoretically the lowest price for TSOs.[9] However, this pricing methodology may disincentivize participation, as participants tend behave irrationally and “bid to get taken”, negatively impacting producer surplus.[1] This is partly mitigated by the fact that Germany has a capacity market, which rewards industrials for standby capacity in addition to delivering energy, generally improving their business case • A substantial part (50-80%, depending on the size of the industrial) of the final electricity price in Germany consists of taxes, grid charges and other fees. This is relatively high compared to other EU countries (~40% on average).[1,2,3,8] As companies tend to assess business opportunities on a percentage difference basis, fluctuations in the electricity price have a smaller signaling effect in Germany than in the other countries		• See context of deviations regarding awareness and presence of mature aggregators of the Netherlands on the previous slide[1] • Based on interviews and similar to in the Netherlands, awareness among industrials on DSR is regarded relatively weak compared to the other EU countries and the maturity of aggregators could be further enhanced through certification or a general code of conduct[1]		• See context of deviations regarding (sub)metering criteria of the Netherlands on the previous slide[1]	

i) German government dictates a ‘capacity reserve’ of 2 GW for events of threats to or disruptions of, the security or reliability of the power supply system. This balancing capacity and energy product is publicly tendered, with first delivery started on 1-10-2020 and ending on 30-9-2022; Source: 1) Expert interview; 2) Clean Energy Wire (2017); 3) Clean Energy Wire (2019, b); 4) smartEn (2020); 5) Pentalateral Forum (201&); 6) JRC (2016); 7) SEDC (2017); 8) PwC (2018, a); 9) Regelleistung (a); Strategy& research

Preliminary discussions with industrials illustrate the operational and financial complexity of industrial DSR

Barriers based on interviews among industrials

Awareness

- Not **fully aware** of opportunities within DSR
- **Misunderstanding** of implication on operational processes
- **Lack of simple information** on benefit and implication of DSR
- Need for **dedicated go-to person or organization** who actively helps unlock potential

Financial barriers

- The **uncertainties in the business case** are too high, i.e. future power imbalance price volatility, changing regulation, variation in DSR product/service offering, financial risks of disrupting the operational processes
- **Return on investment limited** due to upfront investment i.e. software, meters, modification of assets), split revenues with aggregators and opex to participate on the market
- **Timing** of investments in DSR are **challenging** (low prices today vs. cannibalization effect of revenues in the future)

Operational barriers

- **Logistic and organizational challenges**, need for e.g. sophisticated infrastructure across departments, integrated planning to not disrupt core processes, alignment between technical and electricity strategy and additional safety risk of disrupting operational processes (i.e. at refineries)[1,2]
- **Technical requirements** may hinder DSR participation e.g. aged assets (i.e. equipment cannot be turned down/off separately), unqualified (sub)meters i.e. distortion on main meter, response time, minimum bid size

> “Ultimately the main goal of [our industrial] is producing at highest utilization rate as possible, not being a flexibility provider"

Side note
There are numerous case studies from United Kingdom, where industrials leveraged storage facilities on their plants to participate in DSR, without impacting their production process utilization rates. So, optimizing utilization and participating in DSR can go hand in hand

Source: Based on interviews with industrials and aggregators (N=9); 1) Ludwig et al. (2019); 2) Roesch et al. (2019)

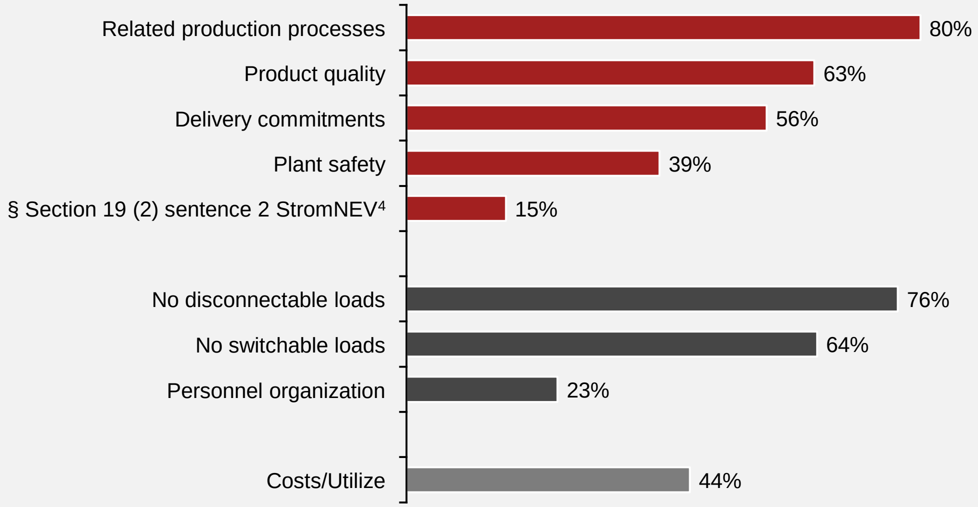
Surveys among industrials show that similar barriers recur in various countries

Barriers based on surveys among industrials

- In both Great Britain and Germany, large-scale surveys were done among **industrial (potential) DSR participants** in 2016 and 2018 respectively
- These surveys can help creating a better understanding where the barriers lie for industrials. In Great Britain, this survey has helped to understand the results of ongoing work [of Ofgem] and inform our subsequent route map with BEIS.
- **Several concerns were found in both surveys** and were mentioned in the interviews this study performed:
  - 🟥 Concerns about the risk or impact on the business
  - ⬛ Uncertainty whether the business is enabled to provide DSR
  - ▩ Uncertainty about the costs and revenues
  - ⬜ Other
- These concerns regarding DSR participation are shared among industrial (potential) participants **across various countries and different years**

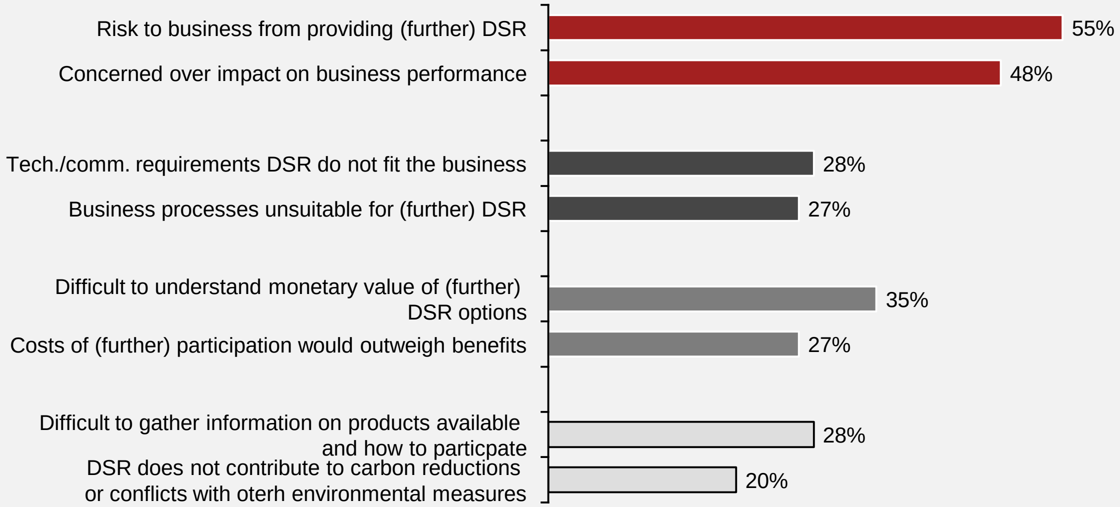
What are the barriers for your company to implement DSR?[1,3]

Germany 2018 | Respondents: 486 industrial companies, ~50% participates in DSR



What are barriers to (further) DSR provision for I&C consumers?[2,5]

Great Britain 2016 | Respondents: 212 (industry, commercial and public sector)



Source: 1) BNetzA (2019); 2) Ofgem (2016,a); 3) Percentages calculated as #respondents/total respondents; 4) states that large electricity users with particularly stable electricity consumption could apply for exemption from network charges; 5) Responses of only non-participating industrials presented – only significant different with the participating industrials was a result of 0% for the answer "Concerned over impact on business performance

The Netherlands could learn from initiatives identified in the study, including a stakeholder led program and an annual survey

Food for thought

Power responsive program

- **What.** Power Responsive is a stakeholder-led program, facilitated by National Grid ESO, to stimulate increased participation in the different forms of flexible technology such as DSR. It brings together industry and energy users, to work together in a coordinated way[1].
- **Why interesting.** The Power Responsive increases the awareness of DSR among DSR providers and shapes the growth of the market in a joined-up way. This ensures that the demand side has equal opportunity with the supply side when it comes to balancing the system[1].

Flex assure

- **What.** Flex Assure is a Code of Conduct scheme which is developed by the industry to set standards of practice for DSR aggregators providing business to business services. It is a voluntary scheme which uses requirements to give customers assurance that they will receive good quality service from registered scheme members[2].
- **Why interesting.** With many energy users new to DSR, it is important they feel confident about the service they will receive from the aggregators. Trust in the aggregator's service is essential. To stimulate this trust, customers could have a common set of standards by which to compare aggregators and their claims.

Annual DSR survey

- **What.** DSR surveys among industrials will give insights into the motivations and barriers why they (do not) participate in DSR. A survey could be integrated in the annual security of supply monitor (Monitor Leveringszekerheid).
- **Why interesting.** Without a clear view on current participation and trends, it is difficult to stimulate DSR[3]. In addition, a survey will increase awareness among potential DSR participants

Source: 1) NGESO (2019, a): 2) Flex Assure (a): 3) Expert interview

6

Appendices

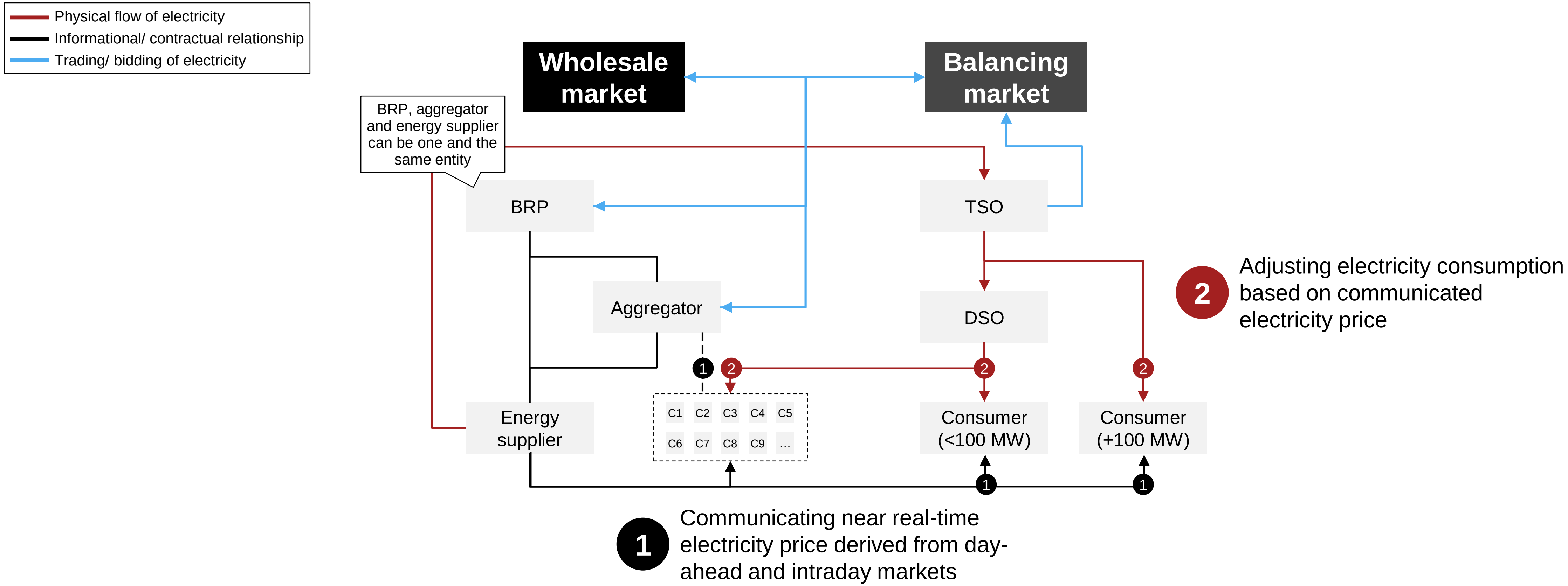
- Illustration of Demand Side Response
- National grid overviews
- Power market overviews
- Abbreviations
- TSO / regulator per country
- Interviewees list
- References and sources
- Corresponding authors
- Disclaimer

Illustration of Demand Side Response

1. Implicit DSR
2. Explicit DSR

Implicit DSR is adjusting electricity consumption triggered by market prices, based on a dynamic pricing contract

Implicit DSR



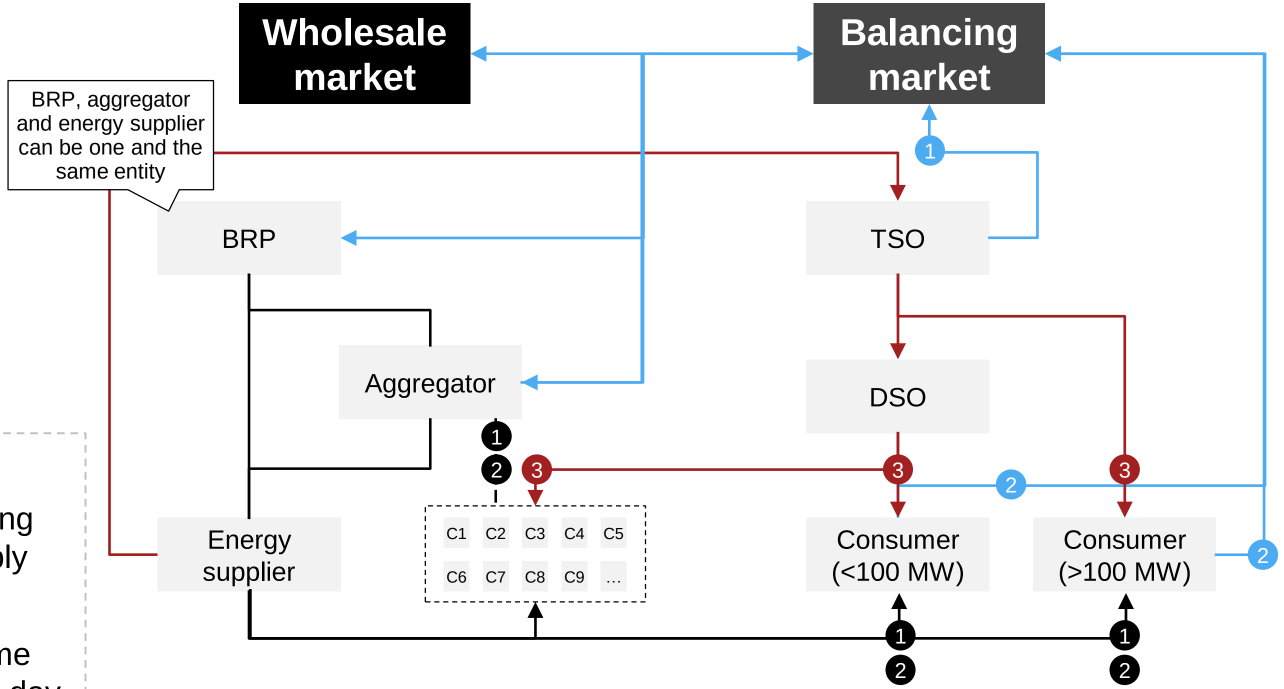
2 Adjusting electricity consumption based on communicated electricity price

1 Communicating near real-time electricity price derived from day-ahead and intraday markets

Explicit DSR is either bidding on tenders or explicitly agreeing on a pricing scheme next to supply contract to benefit from flex

Explicit DSR

— Physical flow of electricity
— Informational/ contractual relationship
— Trading/ bidding of electricity



Option A

1. TSO tenders DSR programs in the balancing market
2. Consumers explicitly bid their flexible capacity on the tenders

Option B

1. Explicitly agreeing on a pricing scheme next to energy supply contract to benefit from flex
2. Communicating near real-time electricity price derived from day-ahead and intraday markets
3. Adjusting electricity consumption based on communicated electricity price

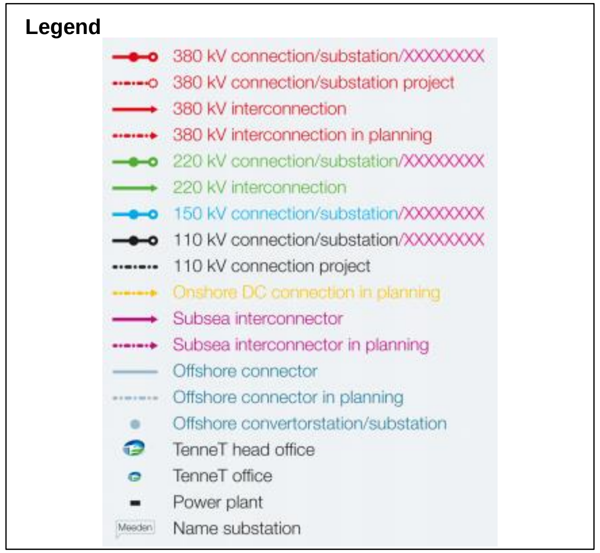
National grid overviews

1. The Netherlands
2. Germany
3. Belgium
4. Great Britain
5. France
6. Denmark

Infrastructure is well-connected, supplying high voltage to major industrial hubs and interconnecting with five countries

Overview of power market – Infrastructure

Interconnection	Technical capacity *(in GW)*		
	2020	**2025**	**2030**
Germany	4.3	5.0	5.0
Belgium	2.4	2.4	3.4
United Kingdom	1.0	1.0	2.0
Norway	0.7	0.7	0.7
Denmark	0.7	0.7	0.7
Total	**9.1**	**9.8**	**11.8**



Insights

- Solid infrastructure with high-voltage connections to major industrial clusters, e.g. Eemshaven, Delfzijl, Velzen (Tata Steel), Maasvlakte, Borssele, Maasbracht (Chemelot)
- Offshore wind parks, e.g. Hollandse Kust (Alpha and Beta)
- High connectivity with nearby countries:
  - 5 interconnections with **9.1 GW** capacity in total
  - **2.7 GW additional** capacity in planning, driving total to 11.8 GW by 2030

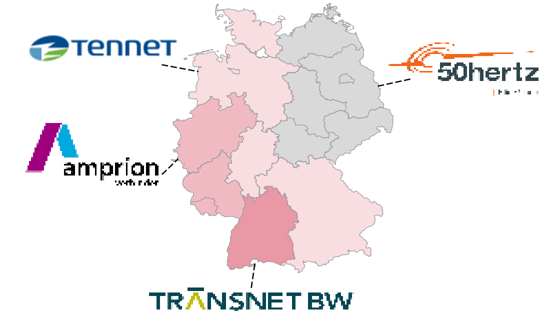
Source: TenneT (2019, b); CBS (a); DNV GL (2020), p. 39; Strategy& analysis

Germany’s highest voltage grid is operated by four TSOs, each covering a region, and is connected to 9 other countries

Overview of power market – Infrastructure

Interconnection	**Technical capacity** *(in GW)*		
	2020	**2025**	**2030**
Austria	4.2	5.7	6.6
Belgium	1.0	1.1	1.8
Switzerland	4.0	4.6	5.7
Czech Republic	2.6	2.6	2.6
Denmark	3.7	3.7	3.7
France	3.0	3.3	4.5
Luxembourg	2.3	2.3	2.3
Netherlands	3.8	4.0	4.6
Norway	1.4	1.6	2.5
Poland	3.0	2.1	3.0
Sweden	0.6	0.7	1.1
Total	**29.6**	**31.7**	**38.4**

Territories



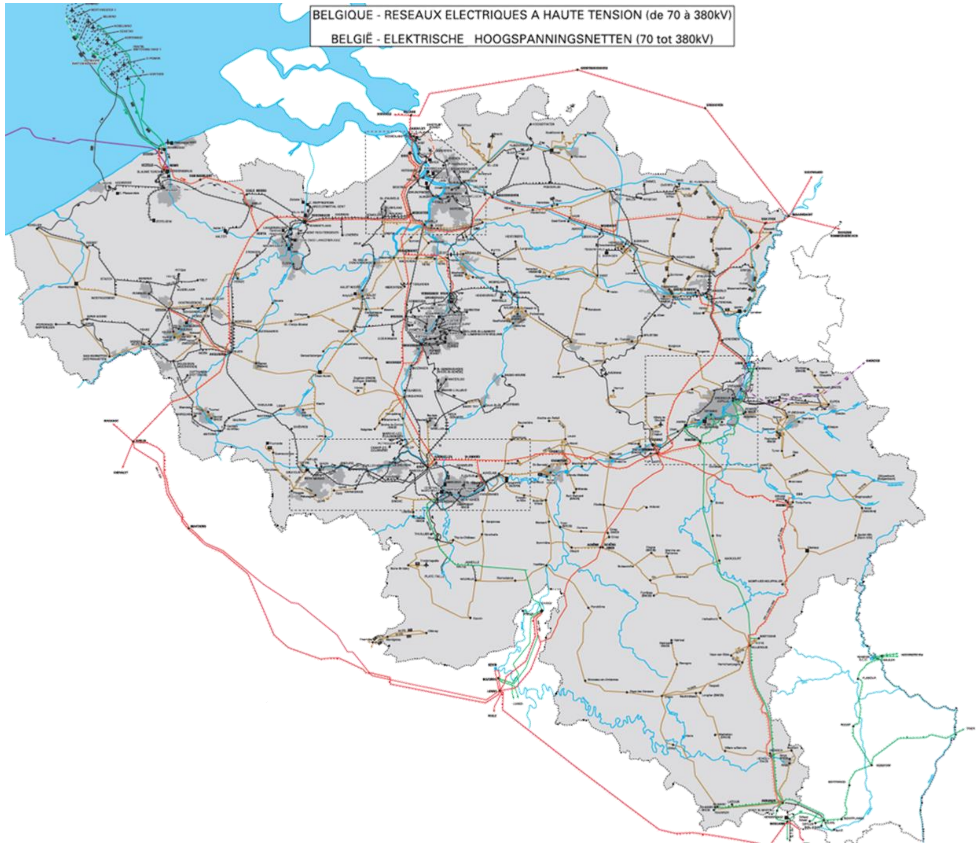
Insights

- Germany’s highest voltage grid (>150kV) is operated by **four different TSOs**: Amprion, TransnetBW, TenneT, and 50Hertz Transmission
- Each of the operators covers a region (one or more states) of the country
- Total **net export** across interconnections is **18.87 TWh**
- High connectivity with nearby countries
  - 12 interconnections with **29.6 GW** capacity in total
  - **8.8 GW additional** capacity in planning, driving total to 38.4 GW by 2030

Source: SMARD (a); VDE FNN (a); r2b (2014), p. 198; Strategy& analysis

Belgium is well connected with four countries and 6.3 GW capacity, with an additional capacity of 3.7 by 2030

Overview of power market – Infrastructure



Interconnection	Technical capacity *(in GW)*	
	2020	2030
Netherlands	2.4	3.4
France	1.9	4.3
United Kingdom	1.0	1.0
Germany	1.0	1.0
Luxembourg[1]		0.3
Total	**6.3**	**10.0**

Legend

━	380 kV
━	220 kV
━	150 kV
━	110 kV
━	70 kV
◆	Nuclear power plant
■	Thermic power plant
□	Thermic power plant[1]
▨	Hydro power plant
■	Hydro power plant
✢	Onshore wind park
✢	Offshore wind park
⬚	Offshore wind park[1]

Insights

- Belgium's high voltage grid (>70 kV to 380 kV) is operated by one TSO: **Elia**
- Total **net export** across interconnections is **1.77 TWh**
- The country's net exporting status is mainly due to their **readily availability** of electricity generated by **nuclear power plants**
- High connectivity with nearby countries:
  - 4 interconnections with **6.3 GW** capacity in total
  - 1 interconnections **(LX)** and **3.7 GW additional** capacity in planning, driving total to 10.0 GW by 2030

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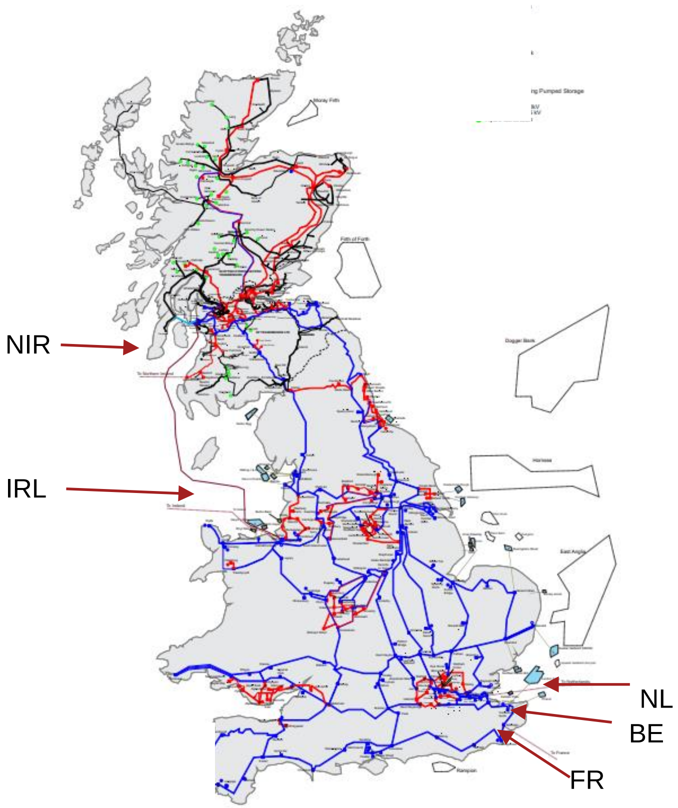
[1] In planning

Source: Elia (2020, a); Elia (2019, a), p. 24; Elia (2017), p. 55; Elia (a); Strategy& analysis

Infrastructure is well-connected, supplying high voltage to major industrial hubs and interconnecting with five countries

Overview of power market – Infrastructure



Interconnection	Technical capacity *(in GW)*	
	2020	2025
France (multiple)	3	5,4
Ireland	0,5	1
Netherlands	1	1
Northern Ireland	0,5	0,5
Belgium	1	1
Norway (2021)		1,4
Denmark (2023)		1,4
Total	**6**	**11,6**

Legend

■ 400kV Substations
■ 275 kV Substations
• 132kV Substations

— 400kV Circuits
— 275kV Circuits
— 220kV Circuits
— 132kV Circuits
— Western HVDC Link
⋯ Interconnectors

Major Generating Sites Including Pumped Storage

⊙ Connected at 400kV
⊙ Connected at 275 kV
⊙ Hydro Generation

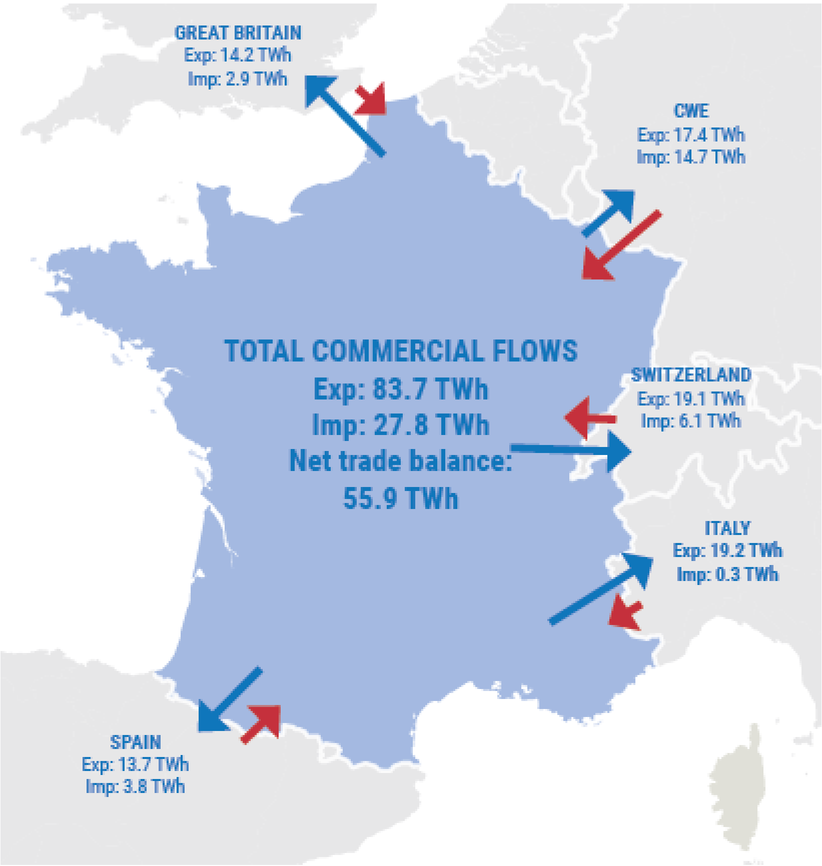
Insights

- Regional transmission companies own and maintain the high-voltage system, while **National Grid Electricity System Operator** (NGESO) operates it
- NG operates the **275kV and 400kV** electricity transmission network
- Total net import across interconnections is 18,1 TWh in 2020
- High connectivity with nearby countries
  - 6 current interconnections with **~5 GW** capacity[4]
  - 5 interconnections in planning (to 2022) with **6,7 GW** capacity
  - The **net import** are estimated **double** in the next 10 years

1) BEIS (2018,a); 2) National Grid (a) note: 01/01/2020, multiplied by 8765 (hours a year); 3) Ofgem (b); 4) BEIS (2020,b); 5) Ofgem (b); 6) EEP (2019)

France is well interconnected and a significant net electricity exporter

Overview of power market – Infrastructure



Interconnection	Technical capacity *(in GW)*
	2020
Germany + Belgium	No data
Great Britain	1,8
Switzerland	2,7
Italy	2,4
Spain	2,2
Total	**9,1 (+DE/BE)**

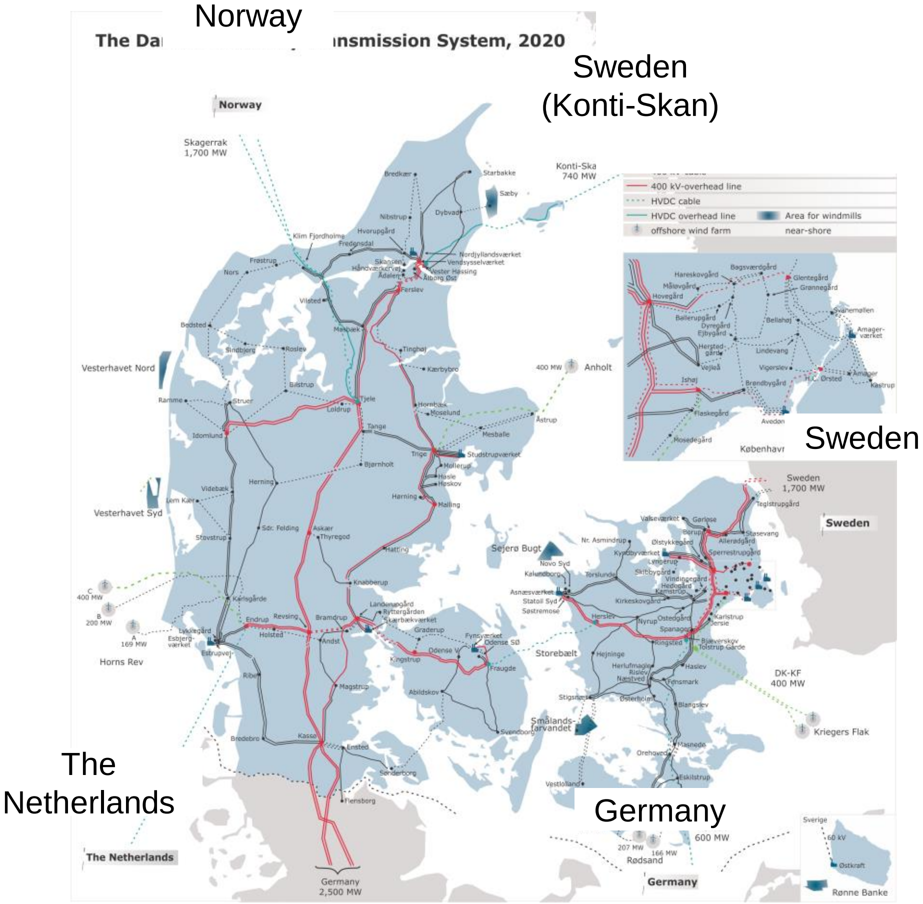
Insights

- RTE's operates at **63 kV, 90 kV, 150 kV** (high voltage) **225 kV and 400 kV** (extra high voltage)
- French **imports and exports show a marked seasonality** due to the sensitivity of French consumption to temperature and the maintenance periods of nuclear power plants
- France consolidates a **central position in the European** energy system being the leading exporter of electricity:
  - The current interconnections with 9,1 GW export and 6,3 GW import capacity (excl. BE and DE)
  - 8 interconnections in planning with 10,7 GW capacity

1) CRE (2020, a); 2) Presents the operational capacity; 3) while the principle of net transfer capacity (NTC) is generally applied, trading capacities in the CWE (incl. Belgium and Germany) region are no longer determined separately by border but in a common way, taking into account the interdependence of flows across borders, following the principle of maximizing the value of trade at regional level. Therefore, this method does not take it possible to calculate exchange capacities by border.

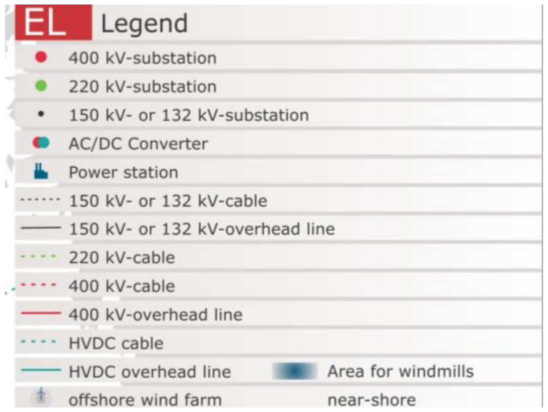
Infrastructure is well-connected, supplying high voltage to major industrial hubs and interconnecting with five countries

Overview of power market – Infrastructure



Interconnection	Technical capacity *(in GW)*	
	2020	2025
Norway	1,7	1,7
Sweden	1,7	1,7
Sweden (K-S)	0,74	0,74
Germany	3,0	4,4
The Netherlands	0,7	0,7
United Kingdom		1,4
Total	**7,84**	**10,64**

Legend


EL Legend

●	400 kV-substation
●	220 kV-substation
•	150 kV- or 132 kV-substation
●	AC/DC Converter
▙	Power station
······	150 kV- or 132 kV-cable
——	150 kV- or 132 kV-overhead line
- - -	220 kV-cable
- - -	400 kV-cable
——	400 kV-overhead line
- - -	HVDC cable
——	HVDC overhead line
▨	Area for windmills near-shore
⍏	offshore wind farm

Insights

- Energinet operates the 400 kV (transmission), 150 kV and 132kV power grids (regional net)
- The system is divided in Western-DK1 (sync. with Germany and continental grid) and Eastern-DK2 (sync. with the Nordic grid)
- Offshore wind parks, e.g. Anholt, Horns Rev 1, 2 and 3, Nysted, Rodsand 2, Krieger Flak
- Total net import across interconnections is ~5 TWh in 2016
- High connectivity with nearby countries
  - 5 current interconnections with 7,3 GW capacity
  - 3 interconnections in planning with 2,8 GW capacity

Source: 1) Energinet (2020,a); 2) DEA (2018); 3) JCR (2016); 4) Danish Ministry of CUE (2019, a)

Power market overview

1. The Netherlands
2. Germany
3. Belgium
4. Great Britain
5. France
6. Denmark

Overview power market – the Netherlands

Ⓐ Overview of power market – Market balancing system

Market	Product	DSR access	Market timeframe	Product requirements	Market participants	Roles of market participants	Who pays for imbalance
Whole-sale markets	**Forward and futures**	Yes	Before Day – 1 12:00	Min: 1.0 MW	BRP, Aggregators, TSO	Optimize portfolio to prevent imbalance	n/a
	Day-ahead	Yes	Day – 45 to Day – 1 12:00	Min: 0.1 MW, daily auction			
	Intraday	Yes	Day – 1 15:005) to 5min6) for delivery	Min: 0.1 MW, continuous trading			
Balancing & ancillary services	**FCR1)** (primary reserve)	No	Day – 14 11:00 to Day – 1 08:00	Min: 1.0 MW, within 30 sec, autom. activated, daily tender, symmetric	BRP, BSP, Aggregators, TSO	Avoid system imbalance, provide balancing energy	BRP
	aFRR2) (regulating power)	Yes	Day – 1 14:45 to 30min for delivery	Min/max: 1/999 MW, within 30 sec, autom. activate, daily tender			
	mFRR3) (reserve power; mFRRsa)	Yes	Day – 1 14:45 to 30min for delivery	Min: 4.0 MW, within 15 min, manual activated, daily tender			
	mFRR4) (emergency; mFRRda)	Yes	Day – 1 14:45 to 30min for delivery	Min/max: 20/100 MW, within 15 min, manual activate, daily tender			

1) Frequency Containment Reserves; 2) automatic Frequency Restoration Reserves; 3) manual Frequency Containment Reserves scheduled activated; 4) manual Frequency Restoration Reserves directly activated; 5) 16:00 for 15 min contracts; 6) 60 minutes for cross-border

Source: SEDC (2017), p. 140-141; ECA (2015), p. 13; E-bridge (2014), p. 45-80; ACER (2018/04); TenneT (2020, b), p. 4,8; TenneT (2019, c), p. 2; EEX (2020), p. 4-7

Overview power market – Germany

A Overview of power market – Market balancing system

Market	Product	DSR access	Market timeframe	Product requirements	Market participants	Roles of market participants	Who pays for imbalance
Trading markets[1]	**Forward and futures**	Yes	Before Day – 1 12:00	Min: 0.1 MW for 15m	BRP, Aggregators, TSO	Optimize portfolio to prevent imbalance	n/a
	Day-ahead	Yes	Day – 45 to Day – 1 12:00	Min: 0.1 MW for 15m, daily auction			
	Intraday	Yes	Day – 1 15:00 1) to 5min 2) for delivery	Min: 0.1 MW for 15m, continuous trading			
Balancing & ancillary markets	**FCR** (PCR)	Yes	Day – 14 11:00 to Day – 1 08:00	Min: 1 MW, within 30s, automatic, max: 1w, daily auction	BRP, BSP, Aggregators, TSO	Avoid system imbalance, provide balancing energy	BRP
	aFRR (SCR)	Yes	Day – 1 12:00 to 25min for delivery	Min: 1 MW, within 5m, automatic, max: 4h, daily auction			
	mFRR (MR)	Yes	Day – 1 12:00 to 25min for delivery	Min: 1 MW, within 12.5 or 15m, automatic, max: 4h, daily auction			
	Interruptible loads	Yes	Day – 8 11:00 to Day – 7 11:00	Min: 5 MW, daily auction			

1) 15:30 for 30 min contracts and 16:00 for 15 min contracts; 2) 60 minutes for cross-border

Source: SEDC (2017) p. 94-104; ECA (2015) p. 13; SMARD (b); EEX (2020), p. 4-7; ENTSOE (d); ACER (2020/02; 2020/03); Strategy& research

Overview power market – Belgium

A Overview of power market – Market balancing system

Market	Product	DSR access	Market timeframe	Product requirements	Market participants	Roles of market participants	Who pays for imbalance
Trading markets	**Forward and futures**	Yes	Before Day – 1 12:00	Min: 0.1 MW for 15m	BRP, Aggregators, TSO	Optimize portfolio to prevent imbalance	n/a
	Day-ahead	Yes	Day – 45 to Day – 1 12:00	Min: 0.1 MW for 15m, daily auction			
	Intraday	Yes	Day – 1 15:00 to 5min[1] before delivery	Min: 0.1 MW for 15m, continuous trading			
Balancing & ancillary services	**FCR** (R1-Load Up)	Yes	Day – 14 to Day – 1 08:00	Min: 1 MW, 15s (50%), 30s (100%), automatic, daily auction	BRP, BSP, Aggregators, TSO	Avoid system imbalance, provide balancing energy	BRP
	aFRR (R2)	No	Day – 14 00:00 to 25min before delivery	Min/max: 1/50 MW, within 30s, max 30min, automatic, daily auction			
	mFRR (R3-DP)	Yes	Day – 14 00:00 to 45min before delivery	Min: 1 MW, within 15m, manual, max. 40 times per year, daily auction			
	mFRR (R3-ICH)	Yes	Day – 14 00:00 to 45min before delivery	Min: 1 MW, within 3m, manual, max. 4 times p.a., daily auction			
	RR (SR)	Yes	n/a	Min: 1 MW, 6.5h (up), 1.5h (down), max. 40 times p.a., yearly auction			

[1] 60 minutes for cross-border

Source: SEDC (2017), p. 49-57; EEX (2020), p. 4-7; Elia (2019, b), p. 30; Elia (2020, b), p. 74; Elia (2020, c), p. 24,75; Strategy& research

Overview power market – Great Britain

A Overview of power market – Market balancing system

Market	Product	DSR access	Market timeframe	Product requirements	Market participants	Roles of market participants	Who pays for imbalance
Trading markets	**Forward trading**	No	2 years – day -2		BRP, aggregator, consumer, supplier	Optimize portfolio to prevent imbalance	n/a
	Day-ahead	Yes	Day -1	1 hour blocks		Optimize portfolio to prevent imbalance	
	Intraday	Yes	Opens 49.5 hours before and closes 1 hour before delivery·	30 min blocks		Optimize portfolio. All trading activity up to gate closure are notified to the Market Operator, Elexon	
Capacity market	**Capacity Mechanism**	Yes	4 years and auctions 1 year			Qualified capacity providers to bid into a competitive auction to provide capacity or reduce demand[6]	BRP
Balancing & ancillary markets	**FCR (Firm Freq-uency Response (FRR)[11]**	Yes	1 hour	1MW, various response speeds[5]		Participant increase generation or reduce demand	
	Enhance frequency response (EFR)	Yes		1 MW, deliver in 1 sec, sustain 30 min		Participant increase generation or reduce demand	
	FRR (Fast Reserve)	Yes		Min. 25 MW[11] Delivery rate >25MW/minute Response time 2 minutes		Participants provide rapid delivery through increasing output or reducing consumption	
	RR (Short-Term Operating Reserve (STOR))	Yes		Up to 2 years ahead, three time a year 3 MW, Sustain minimal 2 hours. Delivery in 20-240 min		Participant increase generation or reduce demand over a set window	
	RR (Demand turn up (DTU))	Yes		1 MW (aggregated), delivery depend on capabilities (2018 average was ~6 hours)		Participant increase their demand during periods of high generation and low demand[7]	
	Triad avoidance	Yes		Avoidance of 3x30 min of the peak demand moments between Nov and Feb		Reduce their demand to moderate their Transmission Network Use of System half-hour charges for entire financial year	
	Various (solely) generating services	Yes	n/a	n/a	n/a	n/a	n/a

1) European Commission (2016); 2) National Grid (b); 3) National Grid © 4) Engie (a) 5) NGESO (2019, a) 6) BEIS (2020, b) 7) Energy UK (2016,a)

Overview power market – France

A Overview of power market – Market balancing system

Market	Product	DSR access	Market timeframe	Product requirements	Market participants	Roles of market participants	Who pays for imbalance
Trading markets	**Forward and futures**	No	+ 48 hours		BRP, consumers, producers, suppliers, aggregators	BRP wants to balance their portfolio	n/a
	Day-ahead	Yes	Closure at 12 noon	0,1 MW			
	Intraday	Yes	24 to 30 min before closure	0,1 MW			
Balancing & ancillary markets	**Primary reserve (FCR)**	Yes	30 min	Min 1 MW 30 sec activation		Mandatory by all new generation (>40MW)	BRP
	Secondary reserve (aFRR)	Yes	30 min	Min 1 MW 15 min activation		Mandatory by all new generation (>120MW)	
	Tertiary reserves (mFRR, RR)	Yes	30 min	Min 10 MW 13 min – 2 hours activation		Mandatory by FR generators. All capacity is paid as bid	
	Demand response call for tender (DSR –RR)	Yes	annual call for tenders	1 MW 2 hours			
Capacity market	**Capacity Remuneration Mechanism**	Yes	4-1 year	Capacity certificates (both generation or DSR)	BRP, consumers, producers, suppliers, traders, aggregators	Suppliers are obliged to buy capacity certificates (generation or DSR) to foresee consumption in peak periods	

Source: 1) European Commission (2016); 2) E-CUBE (2017, a); 3) FTE (2019, a); 4) RTE (2020, a)

Overview power market – Denmark

A Overview of power market – Market balancing system

Market	Product	DSR access	Market timeframe	Product requirements	Market participants	Roles of market participants	Who pays for imbalance
Trading markets	**Forward and futures**	No			BRP, aggregator, TSO	Optimize portfolio to prevent imbalance	n/a
	Day-ahead		Closes a 12 pm on D-1	Max. size 500 MW Traded by the hour			
	Intraday		Closes 60 min before delivery	Min.15 min blocks			
Balancing & ancillary markets	**FCR (primary reserve, frequency-controlled disturbance / normal operation reserve)**	Yes	0-60 min	<15 sec Maintain 15 min Min. 0.3 MW[1]	BRP, BSP, Aggregators, TSO	Buys/sells on daily auctions, activation is merit order	BRP / BSP / Aggregator
	aFRR (secondary reserve)		0-60 min	<15 min Maintain continuously		Buys/sells monthly service, activation is pro rate	
	mFRR (tertiary reserve)		0-60 min	<15 min Size 10-50 MW		Buys/sells on daily auctions, activation is merit order	
	RR		0-60 min				
	Strategic Reserves		0-60 min	One-off tender with participation of consumption and production units			

Source: 1) European Commission (2016); 2) JCR (2016)

Abbreviations

Abb.	Definition
aFRR	Automatic frequency restoration reserve
aFRR	Manual frequency restoration reserve
BM	Balancing Mechanism
BRP	Balance Responsible Party
BSP	Balancing Service Provider
CEP	Clean Energy Package
CPP	Critical Peak Pricing
DNO	Distribution Network Operator
DR	Demand Response
DSF	Demand Side Flexibility
DSO	Distribution System Operator
DSR	Demand Side Response
EDP	Extreme Day Pricing
EFR	Enhanced Frequency Response
EBGL	Electricity Balancing Guideline
FCR	Frequency containment reserve
FFR	Fast frequency response
FR	Fast Reserve
iDSR	Industrial Demand Side Response

Abb.	Definition
ISP	Imbalance Settlement Period
RES	Renewable Energy System
RTP	Real-time Pricing
STOR	Short Term Operating Reserve
ToU	Time of Use
TSO	Transmission System Operator

Countries	
NL	The Netherlands
DE	Germany
FR	France
GB	Great Britain
BE	Belgium
DK	Denmark
ES	Spain

TSO and regulator per country

Country	TSO	Regulator
NL	TenneT	ACM
DE	TenneT, TransnetBW, Amprion, 50 Hertz Transmission	BNetzA
FR	RTE	CRE
GB	National Grid	Ofgem
BE	Elia	CREG
DK	Energinet	DUR
ES	REE	CNMC

Interview list

Country	Organization type	Name organization
BE	Industrial stakeholder organization	Febeliec
DE	Industrial stakeholder organization	BDI
DE	Research institute	DENA
DK	Aggregator	Energi Danmark
ES	TSO	REE (1)
ES	TSO	REE (2)
EU	Regulator	ACER
FR	Regulator	CRE
FR	Aggregator	Energy Pool
GB	TSO	National Grid ESO
GB	Aggregator	Kiwi Power
GB	Regulator	Ofgem
GB	Industrial stakeholder organization	ADE
NL	Regulator	ACM
NL	TSO	TenneT (1)
NL	TSO	TenneT (2)
NL	Aggregator	Centrica
NL	Industrial	Heavy industry manufacturer
NL	Industrial	Aldel
NL	Industrial	BP

References (1/8)

Reference	Author	Title	Year	Type source
ACER (2018/04)	ACER	ACER Decision 2018/04	2018	Regulation
ACER (2020/02)	ACER	ACER Decision 2020/02 - Implementation framework for aFRR	2020	Regulation
ACER (2020/03)	ACER	ACER Decision 2020/03 - Implementation framework for mFRR	2020	Regulation
ACM (2019)	ACM	Verkenning naar belemmeringen voor de rol van aggregator	2019	Document
ACM (2020)	ACM	Ontwerpbesluit toepassing LFDD	2020	Regulation
Ademe (2018,a)	Ademe	French energy mix 2030-2060	2018	Document
Agora (2015)	Agora	A Snapshot of the Danish Energy Transition	2015	Document
Artelys (2019)	Artelys	Determination of a target electricity interconnection capacity between France and the United Kingdom	2019	Document
Barbero et al. (2020)	Barbero et al.	Critical evaluation of European balancing markets to enable the participation of Demand Aggregators.pdf	2020	Article
Behrangrad (2015)	Behrangrad	A review of demand side management business models in the electricity market	2015	Article
BEIS (2018,a)	BEIS	Market Information Report: Great Britain	2018	Document
BEIS (2019, a)	BEIS	Updated energy and emissions projections 2019	2019	Document
BEIS (2020, b)	BEIS	Statutory Security of Supply Report	2020	Document
BEIS (2020,a)	BEIS	Energy Consumption in the UK (ECUK) 1970 to 2019	2020	Document
BloombergNEF (a)	BloombergNEF	Energy Storage Investments Boom As Battery Costs Halve in the Next Decade	n/a	Website
BMWi (a)	BMWi	An electricity grid for the energy transition	n/a	Website
BNetzA (2019)	BNetzA	Monitoringbericht	2019	Document
Borssele Benchmark Committee (2018)	Borssele Benchmark Committee	Safety Benchmark of Borssele Nuclear Power Plant	2018	Document
Cardosa et al. (2020)	Cardosa et al.	Making demand side response happen A review of barriers in commercial and public	2020	Article
CBS (a)	CBS Statline	Statline Elektriciteitsbalans aanbod en verbruik	n/a	Database
Clairand et al. (2020)	Clairand et al.	Review of energy efficiency Technologies in the Food Industry - Trends, Barriers, and opportunities	2020	Article
Clean Energy Wire (2017)	Clean Energy Wire	Power grid fees - Unfair and opaque?	2017	Website

References (2/8)

Reference	Author	Title	Year	Type source
Clean Energy Wire (2019, a)	Clean Energy Wire	German government says power storage capacity could grow more than 50-fold by 2030	2019	Website
Clean Energy Wire (2019, b)	Clean Energy Wire	Industry power prices in Germany: Extremely high – and low	2019	Website
Clean horizon (2019, a)	Clean horizon	Energy Storage Status Overview	2019	Document
CRE (2020, a)	CRE	Electricity and gas interconnections 2020	2020	Document
CREG (2019)	CREG	Jaarverslag 2019	2019	Document
Danish Ministry of CUE (2019,a)	Danish Ministry of CUE	Denmark's Integrated National Energy and Climate Plan	2019	Document
DEA (2018)	Danish Energy Agent	Energy in Denmark	2018	Document
DEA (2020, a)	Danish Energy Agent	Denmark's Climate and Energy Outlook	2020	Document
Deloitte (2015)	Deloitte	European energy market reform; country profile: Spain	2015	Document
Deloitte (2016)	Deloitte	A sustainable energy model for Spain in 2050	2016	Document
Dena (a)	Dena	More flexibility through demand side management	n/a	Website
DNV GL (2020)	DNV GL	Rapportage Industriële Vraagrespons	2020	Document
DNV GL (2020, a)	DNV GL	A state of the art review of demand side flexibility	2020	Document
E-bridge (2014)	E-bridge	Potential cross-border balancing cooperation between the Belgian, Dutch and German electricity TSOs	2014	Document
ECA (2015)	ECA	European Electricity Forward Markets and Hedging Products	2015	Document
E-CUBE (2017,a)	E-CUBE	Assessment of demand response potential in industry and services in metropolitan FR	2017	Document
E-CUBE (2020)	E-CUBE	2030 Peak Power Demand in North-West Europe	2020	Document
EEP (2019)	EEP	Annex-J-total-electricity-gen-by-source	2019	Database
EEX (2020)	EEX	Trading on EPEX SPOT 2020	2020	Document
Elia (2017)	Elia	Adequacy report	2017	Document
Elia (2019, a)	Elia	Duurzaamheidsverslag 2019	2019	Document

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Elia (2019, b)	Elia	FCR Service Design Note	2019	Document
Elia (2019, c)	Elia	CRM Design Note; Derating factors	2019	Document
Elia (2019, d)	Elia	Adequacy and Flexibility Study for Belgium 2020-2030	2019	Document
Elia (2020, a)	Elia	High Voltage Power Grid Map	2020	Document
Elia (2020, b)	Elia	T&C BSP aFRR	2020	Document
Elia (2020, c)	Elia	BSP Contract mFRR	2020	Document
Elia (a)	Elia	Yearly capacity (interconnections)	n/a	Website
Ember (a)	Ember	Global Electricity Production Mix 2000-2019	n/a	Database
ENEFIRST (2020)	ENEFIRST (EU comm)	PARTICIPATION OF DEMAND RESPONSE IN FRENCH WHOLESALE ELECTRICITY MARKET	2020	Document
Energiewet (2020)	Min van EZK	Wetsvoorstel Energiewet	2020	Regulation
Energinet (2015, a)	Energinet	Electricity market of the future	2015	Document
Energinet (2019, a)	Energinet	Security of Supply	2019	Document
Energinet (2020, a)	Energinet	The Danish Transmission Electricity system 2020	2020	Website
Energinet (a)	Energinet	Danish electricity retail market	n/a	Document
Energy Storage news (2020)	Energy Storage news	UK industry welcomes Capacity Market changes that enable wider energy storage participation	2020	Website
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Energy Web (2018)	Energy Web	Belgium's Transmission System Operator Eyes Blockchain for Demand Response	2018	Website
Energyst (2019,a)	Energyst	Demand Side response 2019 report	2019	Document
Engie (a)	Engie	Understanding the capacity market	n/a	Document
ENTSOE (a)	ENTSOE	Installed Capacity Germany	n/a	Database
ENTSOE (b)	ENTSOE	Installed Capacity Netherlands	n/a	Database

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Reference	Author	Title	Year	Type source
ENTSOE (c)	ENTSOE	Installed Capacity United Kingdom	n/a	Database
ENTSOE (d)	ENTSOE	Frequency Containment Reserves (FCR)	n/a	Website
ENTSOE (e)	ENTSOE	Installed Capacity Denmark	n/a	Database
ENTSOE (f)	ENTSOE	Mid-term Adequacy Forecast 2020 (MAF 2020)	2020	Database
ESN (2020)	The Energy Storage Network	Electricity Storage: Pathways to a Net Zero Future	2020	Document
EU (2017/2195)	European Commission	Regulation EU 2017-2195; establishing a guideline on electricity balancing	2017	Regulation
EU (2019/943)	European Commission	Regulation EU 2019-943; on the internal market for electricity	2019	Regulation
European Commission (2016)	European Commission	Overview of European Electricity Markets	2016	Document
European Commission (2019)	European Commission	Integrated National Energy and Climate Plan Spain 2021-2030	2019	Document
European Commission (a)	European Commission	Clean Energy Package	n/a	Website
European Commission (2018)	European Commission	Study on the quality of electricity market data of transmission system operators, electricity supply disruptions, and their impact on the European electricity markets	2018	Document
Eurostat (a)	Eurostat	Electricity Balance by Country and Industry	n/a	Database
Febeliec (2013)	Febeliec	Demand Response Survey	2013	Document
Febeliec (2019)	Febeliec	Position Paper on Demand Side Flexibility	2019	Document
FED (a)	FED	Industrial Production and Capacity Utilization	n/a	Website
Flex Assure (a)	Flex Assure	About Flex Assure	n/a	Website
FOD Energie (2019)	FOD Energie	Belgian Electricity Market Implementation Plan	2019	Document
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Modliborska et al. (2020)	Modliborska et al.	ASSESSMENT OF THE DEVELOPMENT OF DEMAND SIDE	2020	Article
MRC (2020)	MRC consultancy	Report on storage and DSR in Spanish Market	2020	Website
National Grid (2017, a)	National Grid	Snapshot on value stacking of demand side flexibility from different GB markets	2017	Document
National Grid (2017, b)	National Grid	Realising the potential of Demand-side response to 2025 (small user focus)	2017	Document
National Grid (2019)	National Grid	De-rating Factor Methodology for Renewables Participation in the Capacity Market	2019	Document
National Grid (a)	National Grid	National Grid: Live Status	n/a	Website
National Grid (b)	National Grid	Fast Reserve	n/a	Document
National Grid (c)	National Grid	STOR	n/a	Document
Netcode Elektriciteit (2020)	ACM	Netcode elektriciteit	2020	Document
NGESO (2019, a)	NGESO	Power Responsive Annual Report	2019	Document
NGESO (2020, c)	NSESO	Frequency Response Auction Trial Evaluation Report Final v1.0	2020	Document
NGESO (b)	NGESO	Balancing Services	n/a	Website
Ofgem (2014)	Ofgem	Electricity Capacity Assessment Report	2024	Document
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PwC (2018, a)	PwC	Vergelijking van gas- en elektriciteitsprijzen 2017	2018	Document
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REA (2019, a)	REA	Energy Transition Readiness Index	2019	Document
REE (a)	REE	International interconnections	n/a	Website
REE (b)	REE	Strengthening interconnections	n/a	Website
REE (c)	REE	Interruptiblility service	n/a	Website
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SEDC (2017, a)	SEDC	The potential of Demand Response in Europe	2017	Document
Seo et al. (2020)	Seo et al.	Optimal demand response operation of electric boosting glass furnaces.pdf	2020	Article
SERV (2018)	SERV	FOPlan van Elia in 3D en in 360graden perspectief	2018	Document
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Shoreh et al. (2016)	Shoreh et al.	A survey of industrial applications of Demand Response	2016	Article
Sia Partners (2014)	Sia Partners	Demand Response : A study of its potential in Europe	2014	Document
SMARD (a)	SMARD	Cross-border Physical Electricity Flows Germany	n/a	Database
SMARD (b)	SMARD	Electricity market explained - Wholesale prices	n/a	Website
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SmartEN (2020, a)	smartEN	EU Regulation Implementation Monitoring Report	2020	Document
Sousa and Soares (2020)	Sousa and Soares	Demand response, market design and risk A literature review	2020	Article
TenneT (2018, a)	TenneT	Productinformatie aFRR	2018	Document
TenneT (2019, a)	TenneT	Flexibility Monitor	2019	Document
TenneT (2019, b)	TenneT	High Voltage Grid Map	2019	Document
TenneT (2019, c)	TenneT	Productinformatie mFRRda	2019	Document
TenneT (2020, a)	TenneT	Rapport Monitoring Leveringszekerheid 2018-2034	2020	Document
TenneT (2020, b)	TenneT	Manual Bidding of Balancing- and Transport Power	2020	Document
Tennet (2020, c)	TenneT	Annual Report 2020	2020	Document
TenneT (2021)	TenneT	Monitoring Leveringszekerheid 2020	2021	Document
TenneT (a)	TenneT	Annual Peak Load	n/a	Website
TenneT (b)	TenneT	Hoogspanningsnet Nederland	n/a	Website
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uFE (a)	uFE	Demand Response, a promising segment for the flexibility of the electricity system	n/a	Website
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Warren (2015)	Warren	PhD - Demand-Side Management Policy - mechanisms for success and failure	2015	Article
Wirtschaft NRW (2018)	Wirtschaft NRW	Versorgungssicherheit	2018	Document

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- PwC has prepared a public report *Unlocking Industrial Demand Side Response*, dated 26-03-2021 (hereafter: the ‘Report’) at the request of the Client. The Report is addressed to the Client and has been prepared for the sole benefit and use of the Client.
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