WHEN TRUST MATTERS

Boosting flexibility in distribution grids

Report for Agora Energiewende

Agora Energiewende

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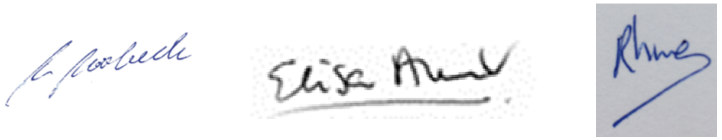				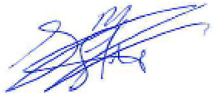	

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Executive summary

Executive summary (1/2)

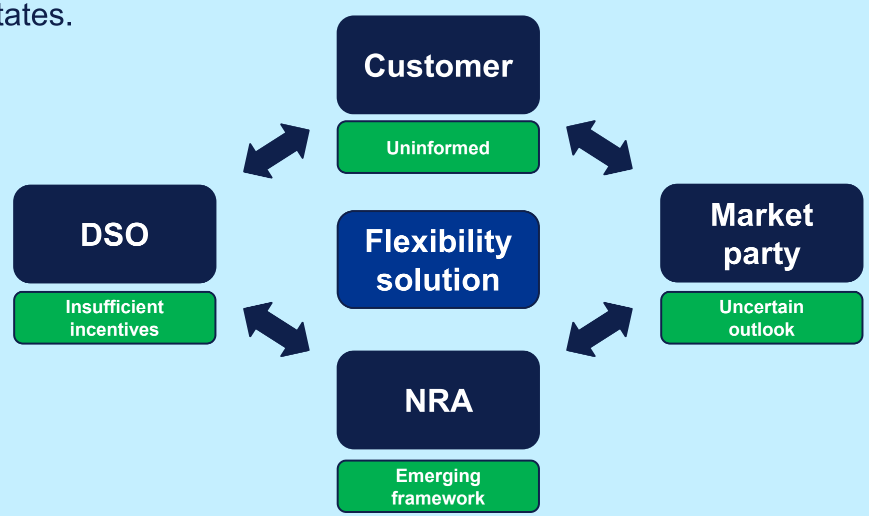
DNV's assessment of European Distribution System Operators (DSOs) reveals pressing challenges in grid capacity, hindering decarbonization and integration of renewables and other low-carbon technologies. Stakeholders, including DSOs and regulators, acknowledge the escalating issue of grid scarcity demands urgent attention, as it poses a bottleneck to meeting sustainable targets.

Substantial grid reinforcements are needed and are foreseen. Yet, this "traditional way" of meeting growing customer demand is insufficient due to long permitting processes, shortages of workforce with the needed skills and not enough regulatory/financial incentives. Since the pace at which grid reinforcements are carried out is too low, alternative solutions need to be implemented by DSOs, such as demand side flexibility (DSF) mechanisms, technical solutions, or smart operation solutions. Stakeholders stress the non-exclusive nature of grid reinforcements and other solutions, since both need to be implemented to address grid capacity scarcity.

This project focuses on demand side flexibility solutions that enable the adjustment of generation or demand to achieve a balanced and efficient electricity system. Within these solutions, we deep dive into non-firm connection agreements and time of use grid tariffs identified by DSOs in this project to have the largest potential in the short-term, with flexibility markets being at a less mature development stage in some Member States.

Shortening the implementation time of DSF mechanisms is essential as, having assessed the maturity of the different solutions and their potential implementation timelines, the question remains whether DSOs can implement the solutions in time to avoid scarce grid capacity remaining a bottleneck for the energy transition.

Flexibility solutions are at the centre of a complex ecosystem, where every party seems to be waiting for the others to take the lead. **Market parties** experience uncertainty as a barrier to participate in DSF. The **DSOs** seem to await guidance and incentives to further develop DSF solutions, also suffering from non-participating **customers.** Meanwhile, **NRAs** expect the DSF initiatives to come from DSOs, developing the regulatory framework as demanded, being potentially overdue. An overview of the four key stakeholders around the flexibility solutions is provided on the right-hand side, with their challenges included.



Executive summary (2/2)

DNV recommends **NRAs** to:

- Incentivise DSOs to significantly accelerate the implementation and deployment of flexibility solutions; encouraging and fairly compensating DSOs to develop these solutions, empowering them to lead this effort. To date, DSOs tend to await regulation to be in place to invest in developing and implementing flexibility solutions. This is because DSOs and companies need long-term certainty to make the investments in flexible solutions. DNV recommends providing further certainty with for e.g., regulatory commitments and longer-term planning.
- Develop the regulatory frameworks, not only to assess DSOs on reliability and affordability, but also on sustainability, allowing an appropriate return of investment for DSOs that are able to connect a higher share of renewables and low carbon technologies.
- Ensure the speedy transposition of the European regulations such as the EU Electricity Market Regulation and Directive. This is indicated by various reports already (e.g. “The implementation of the electricity market design to drive demand-side flexibility” by SmartEn).
- Stimulate customers to unlock their flexibility.

DNV recommends **DSOs** to:

- (1) quantify the capacity scarcity, (2) quantify the potential of each flexibility solution for the different purposes for which it can be implemented (3) formulate a strategy to implement the relevant solutions within a certain timeline. This will enable optimal and strategic long-term planning, operation and investment.
- Build a catalogue of solutions that are effective and share these best practices.
- Coduct a self-assessment to better understand to what degree their organizations are ready/prepared for the energy transition.

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1. Context – The role of the DSO

Index 1. Context – The role of the DSO

1.1 DSOs in transition: challenges and opportunities

The DSO has a key role in the energy transition

General

In Europe, there are thousands DSOs with different characteristics; sizes, voltage levels, locational environments (urban, rural, industrial) and regulatory contexts. Regardless of their seeming disparity, DSOs face comparable challenges, now or in the coming years. The traditional grid reinforcements may not always be the most cost efficient solution and even if they were, they cannot meet the pace by which Variable Renewable Energy Sources (VRES), batteries and low carbon technologies (LCTs) are installed today. Having a more flexible system able to adjust depending on the generation and demand characteristics will be a key lever in achieving a well functioning energy system and meeting climate targets. Therefore, it is crucial to determine to what extent flexibility can contribute and how it can be implemented to actively manage congestion, connect more customers and alleviate the DSO system.

This study

The study explores the role of the DSO that needs to plan, build and operate the grid in a transforming energy system aiming for near decarbonization by 2035. Concretely, the study shall identify the challenges and opportunities of the DSOs, the array of solutions available to enhance flexibility in the system, obstacles & stakeholder concerns and their interaction with regulation.

1.2 Scope and approach

Agora Energiewende’s interest in the outcomes of this study/purpose of this project

Client’s need

The Client would like to present a clear standpoint regarding how DSOs can plan their efforts and investments efficiently to upgrade and adapt their grid and make it suitable for a decarbonized electricity system by 2035. The overall approach is depicted on the right-hand side.

For this study, three Stakeholder Committee Meetings are conducted, with varying objectives:

1. **Stakeholder Committee meeting 1:** share the results of the seven DSO interviews and actively listen to the DSOs participating and get further insight on the challenges they are experiencing and their progress and experience with the flexibility solutions available. Two deep dive solutions are selected.

2. **Stakeholder Committee meeting 2:** confirming the position of DSOs, the flexibility solutions, and their main barriers. It will already focus on the deep dive solutions selected and especially the national regulations for these deep dive solutions. In this meeting a wider stakeholder group is invited.

3. **Stakeholder Committee meeting 3:** recommendations are shared and disseminated.

The final outcome of this study is to provide all stakeholders and decision makers with a clear and reliable position on the role the DSOs will have in the energy transition, the challenges and opportunities of the system today, the array of solutions available, obstacles & stakeholder concerns and their interaction with regulation.

Interaction with Agora through update and coordination and meetings

Approach	WP
Kick off • Detailing scope, methodology and deliverables • Preliminary list of regulations that will be included in assessment	0
Flexibility in distribution systems • T1.1 – DSOs in Europe • T1.2 – Flexibility in the DSO grid • T1.3 – Stakeholder Committee meeting 1	1
Flexibility solutions in the DSO grid • T2.1 – Solutions available to the DSO grid • T2.2 – Solutions in EU and National Regulation • T2.3 – Stakeholder Committee meeting 2	2
Main barriers for boosting flexibility • T3.1 – Main barriers to the implementation of flexible solutions • T3.2 – Deep dive of key solutions • T3.3 – Regulatory recommendations	3
Project finalization • T4.1 – Stakeholder committee meeting 3 • T4.2 – Submission of draft report • T4.3 – Submission of final report	4

1.3 Variety of DSOs selected for the analysis

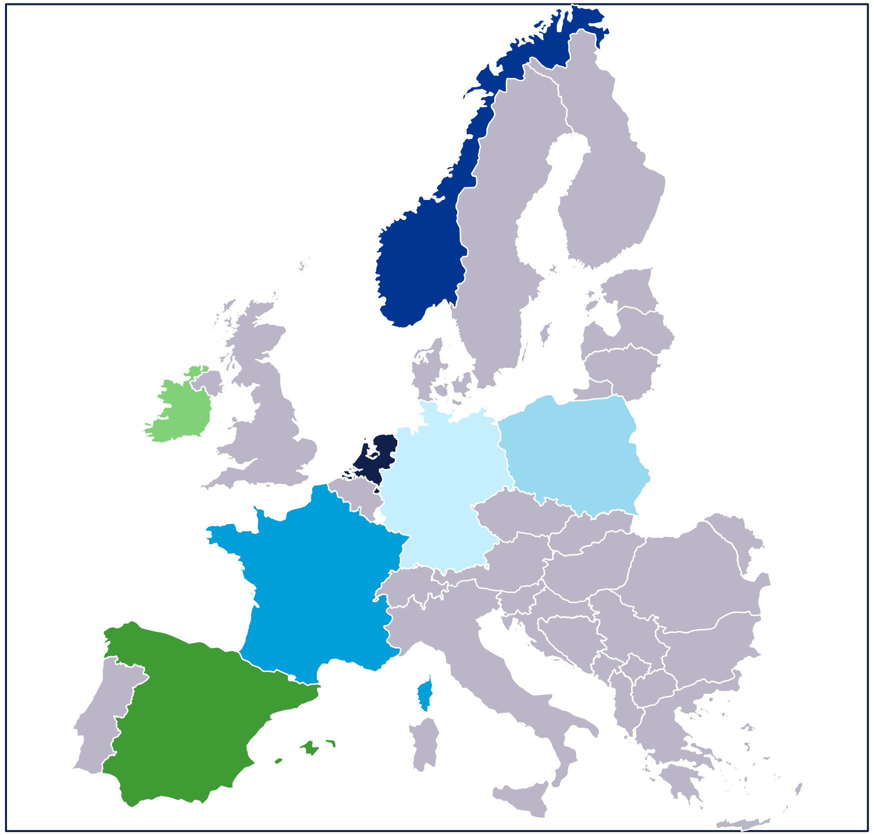
Interviewed DSOs are selected by ensuring variety in size, voltage level, locational environment

Interviewed DSOs are clustered using the categorization method from the JRC (Joint Research Centre, 2023). Norway, even though outside the EU, has been added to provide for an advanced reference case. Selected and clustered DSOs are listed below.

Cluster	Area (km2)	Energy (GWh/km²)	Customers (M)
Small	> 1000	≤ 10	≤1
Medium	> 1000	≤ 10	> 1 & ≤10
Urban	≤ 1000	> 10	-
Big	> 1000	-	> 10

No.	DSO	Country	Cluster
1	Enedis	France	Big
2	I-DE	Spain	Big
3	Elvia	Norway	Small
4	ESB	Ireland	Medium
5	Alliander	Netherlands	Medium
6	E.ON	Germany*	Big
7	Energa	Poland	Big

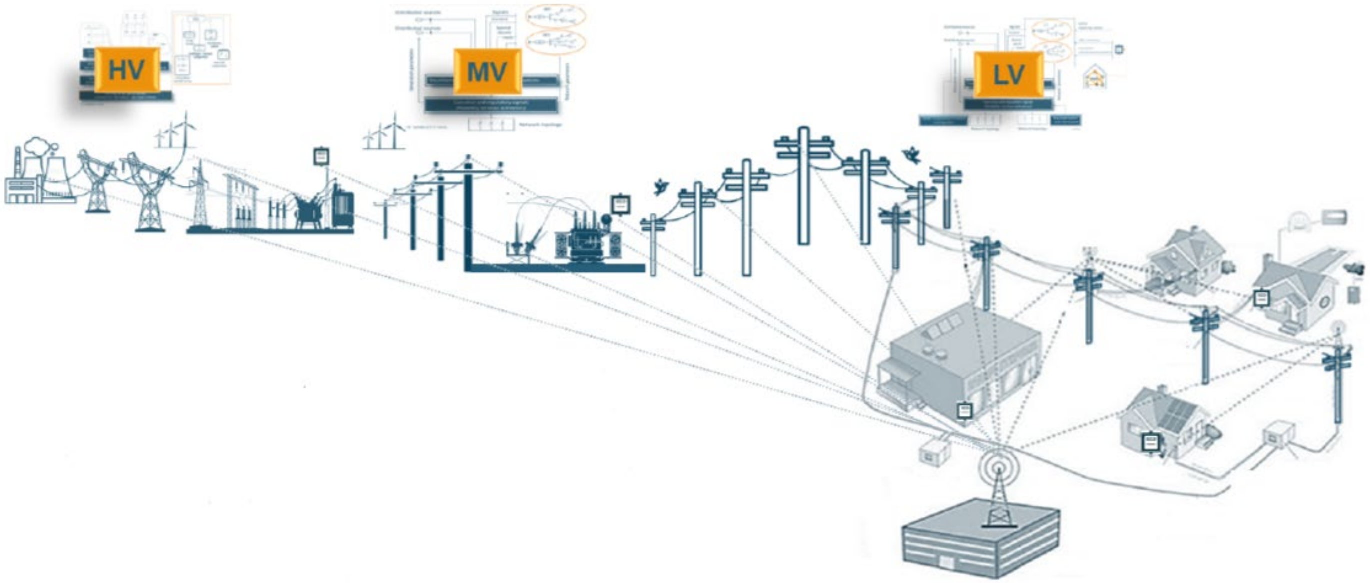
Selected countries



*E.ON has subsidiaries in the Netherlands, France, Germany, the Czech Republic, Hungary, Slovakia, Bulgaria, and Romania, and other European countries.

1.4 The DSO has a critical role in the energy transition

Distribution System Operation Introduction



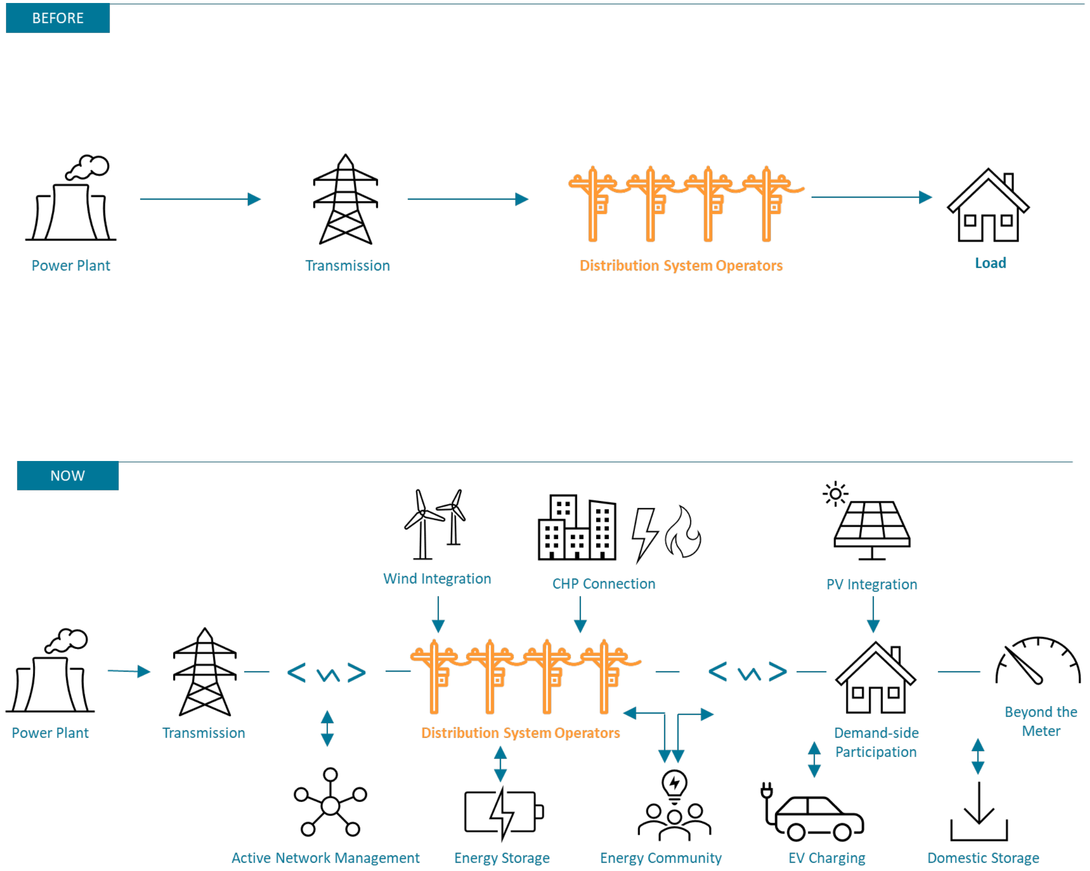
- DSOs are responsible **for distribution network operation, management and planning**.
- DSOs operate at **low (LV), medium (MV) and high voltage (HV)**, with differing levels of grid observability.
- Grid observability is defined as 'temporal, geospatial and topological awareness of all grid variables and assets'.
- Currently **full observability of the distribution networks is achieved at HV level**, the MV network having elements that enable some observability, and LV observability being low, as there has not been a need for full observability at the LV level combined with a long lifetime.

Source: Grid Observability for Flexibility (E.DSO Active Network Management Task Force, 2022)

1.4 The DSO has a critical role in the energy transition

Paradigm shift – most connections at DSO level, with demand able to follow supply

- DSO grids have traditionally been fully passive, based on a 'fit and forget' strategy, compared to the actively operated transmission grids. To achieve the continuous balance between supply and demand necessary for a well functioning electricity system, in the past, only dispatchable generation such as gas was adjusted, having electricity supply following demand.
- Nowadays however, there is **a paradigm shift happening in which demand (such as electric vehicle charging) is becoming adjustable and can follow supply**, as more solar and wind generation gets connected that cannot be ramped up (only ramped down with renewable energy curtailment).
- With many more connections at DSO level**, there is a growing need for distribution grids to be actively managed**.
- Consequently, **the DSO will have a fundamental role in the energy transition**, considering:
  - The ambitious RE generation targets, with around 70% of renewables being connected at DSO level.
  - An unprecedented volume of electrified loads such as EVs and heat pumps that also need to be connected to DSO grids.



Source of diagram: E.DSO Asocodis Conference

1.5 Reading guide

From DSO challenges to flexibility solutions and key messages

Chapter 2.
Challenge

Focuses on the challenge DSOs are facing.

Chapter 3.
Solutions

Explores grid capacity management solutions. Grid reinforcements will be insufficient to address the grid scarcity challenge. Three alternatives: Demand side flexibility, technical solutions, N-1 smart operation.

Chapter 4.
Status of solutions

Focuses on presenting the findings of the discussions with DSOs, assessing the status of each DSF solution.

Chapter 5.
Deep dive selected solutions

Does a deep dive into ToU tariffs and non-firm connection agreements as these were identified by DSOs as the most mature for the moment, and therefore, the most able to have significant short-term impact.

Chapter 6.
Findings and key messages

Concludes and provides key messages from the Stakeholder Committee Meetings.

2. Challenge – Capacity network scarcity

Index 2. Challenge – Capacity network scarcity

2.1 Limited capacity is a barrier to the energy transition

2.2 Structural changes are required to solve the issue

2.3 RE generation and peak demand is rapidly growing

2.4 What has led to this situation?

2.5 The impact of grid scarcity is significant

2.6 Current four key drivers of grid scarcity

2.1 Limited capacity is a barrier to the energy transition

DSOs put into perspective the urgency of the issue

Severity of the issue:

6/7 DSOs interviewed have parts of their HV and MV grid with insufficient grid capacity. 4/7 in LV.

There is an insufficient grid capacity issue if there is a gap between the grid available capacity and grid utilization needs (primarily driven by the connection of RES and electrified loads) that continues to widen.

Extent of the issue:

6/7 DSOs interviewed report facing both feed-in and offtake grid limitations.

- **Offtake** with new businesses and electrified loads being unable to connect to the grid.
- **Feed-in** limiting the integration of renewable energy sources, as there is limited grid capacity to absorb the sustainable generation.

Urgency of the issue:

5/7 DSOs interviewed experience insufficient grid capacity today at MV or LV

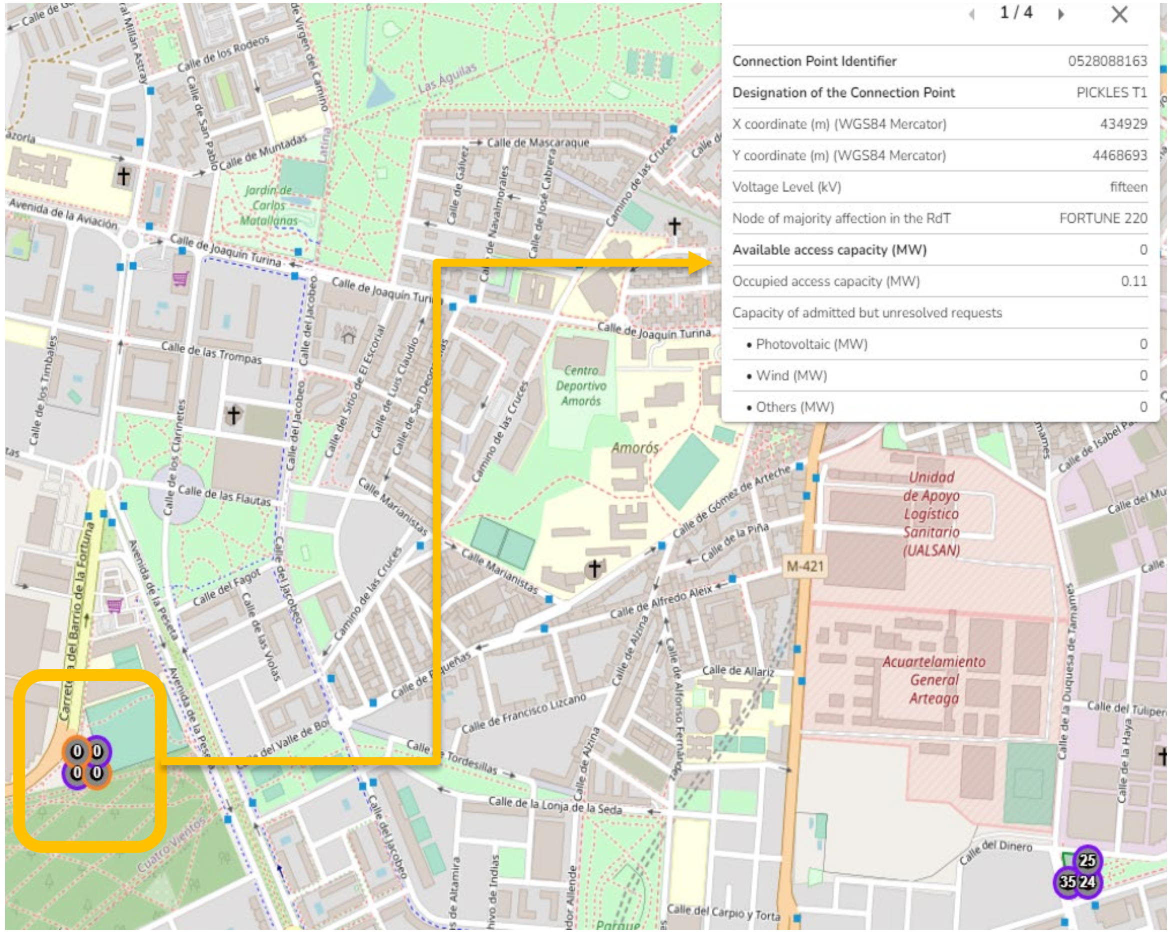
DSOs that are not experiencing limitations at MV or LV at the moment, expect these in 2024-2027

2.2 Structural changes are required to solve the issue

There are increasing sections of network with no capacity available

7/7 DSOs report quantifying their (potential) capacity limitations.

- Carrying out grid reinforcement to increase the network capacity has always been part of the daily DSO business.
- Nonetheless, the network capacity scarcity situation most DSOs are experiencing differentiates from the business as usual as there are higher volumes of network scarcity, that are continuing to increase and that can not be resolved with grid reinforcements in time.
- DSOs are quantifying the (potential) network capacity scarcity and visualising it through detailed maps.
- DSOs report having numerous renewable and demand connection requests in their backlog that cannot be connected at the moment. They acknowledge that only a portion of those applications would transform into realised projects for new generation and demand, as requesting is one of the first steps, and then the project might be realised or not.
- Nonetheless, this portion is still significant and is hampering Europe's development, thereby being a bottleneck for the energy transition.



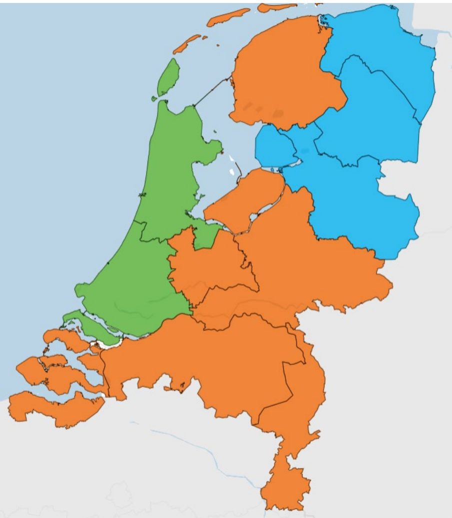
Source: I-DE Capacity map

2.2 Structural changes are required to solve the issue

E.g., in the Netherlands – transmission level congestion extended to DSO level

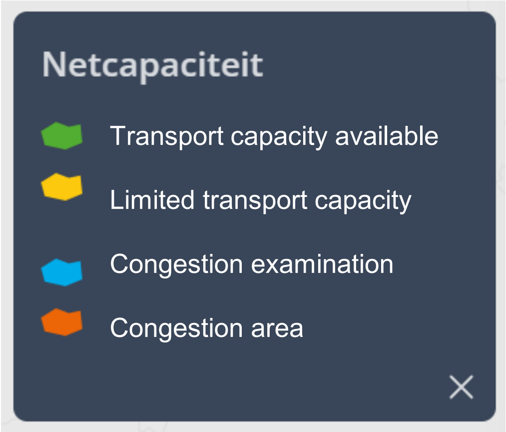
offtake transmission congestion

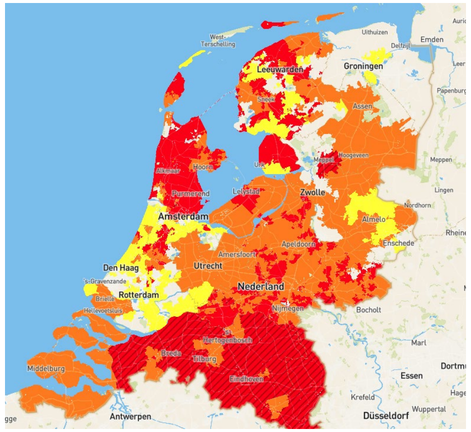
Source: TenneT Afname



In feed transmission congestion

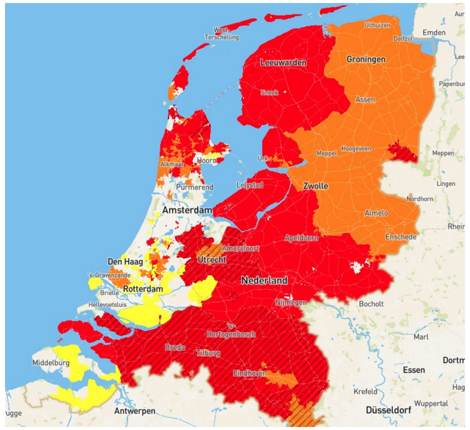
Source: TenneT Invoeding





offtake distribution congestion

Source: Netbeheer Netherlands Afname



In feed distribution congestion

Source: Netbeheer Netherlands Invoeding

Meaning of the color codes

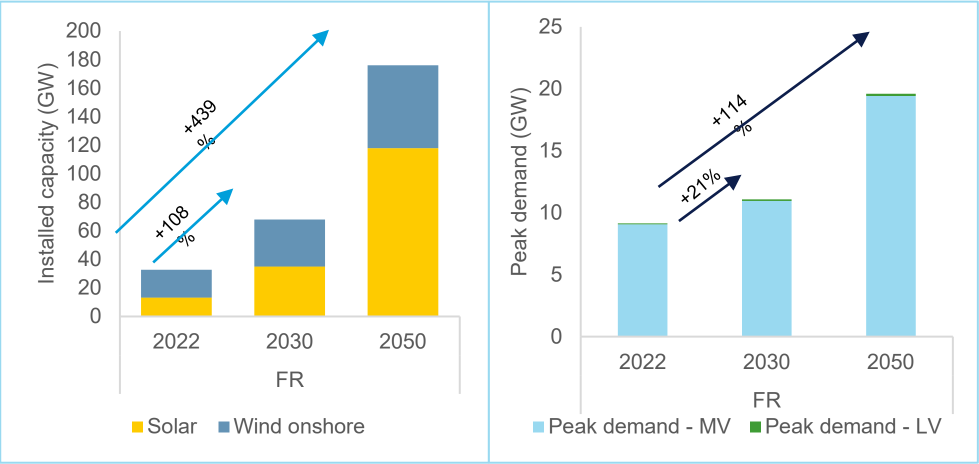
- Transparent: Transport capacity available
- Yellow: Limited transport capacity available
- Orange: No transport capacity available for the time being pending the outcome of the congestion management study
- Red: No transport capacity available: congestion management cannot be applied

With congestion management:

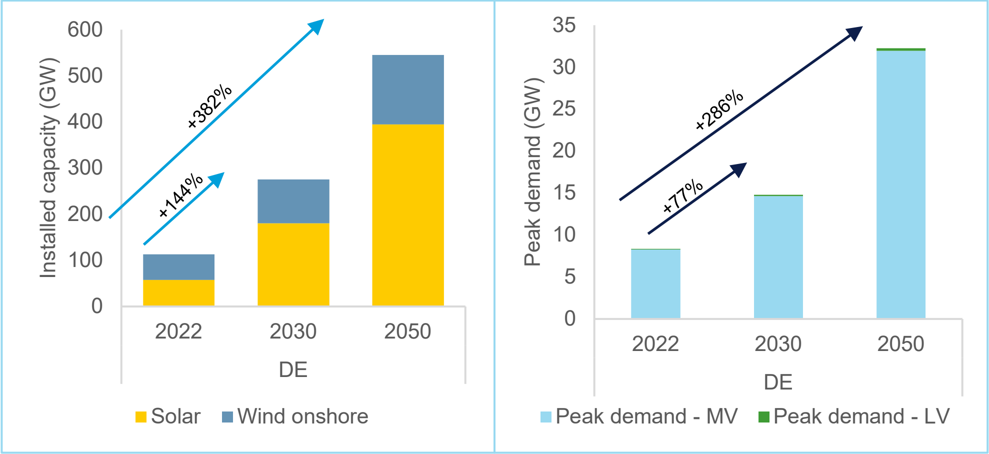
- Transparent hatched: Transport capacity available based on application of congestion management
- Shaded yellow: Limited transport capacity available based on application of congestion management
- Shaded orange: No transport capacity available for the time being pending distribution of the released capacity over the queue based on congestion management. (it is still unclear whether and how much power will become available for new requests that are not yet in the queue)
- Shaded in red: No transport capacity available: the limits for the application of congestion management have been reached.

2.3 RE generation and peak demand is rapidly growing

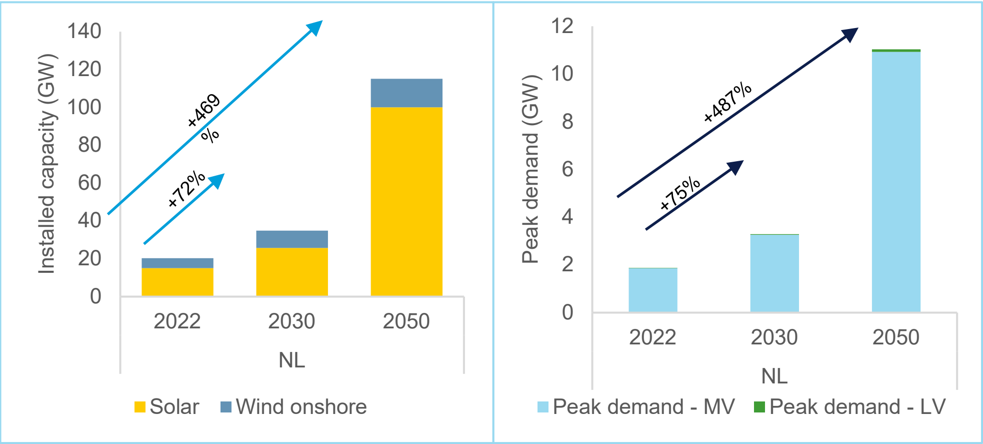
France



Germany



Netherlands

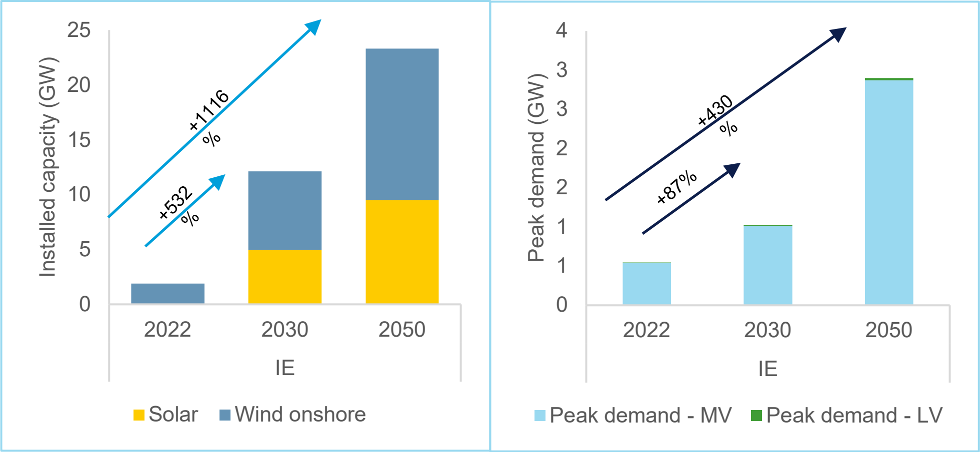


- In **all countries** studied and interviewed, the graphs show a **substantial upward trend** of renewable installed capacity and peak demand for the year 2030 and 2050.
- With network capacity limitations being experienced already today, **the graphs predict further and more drastic demands from the distribution networks**.
- Peak demand increase mostly at MV level.

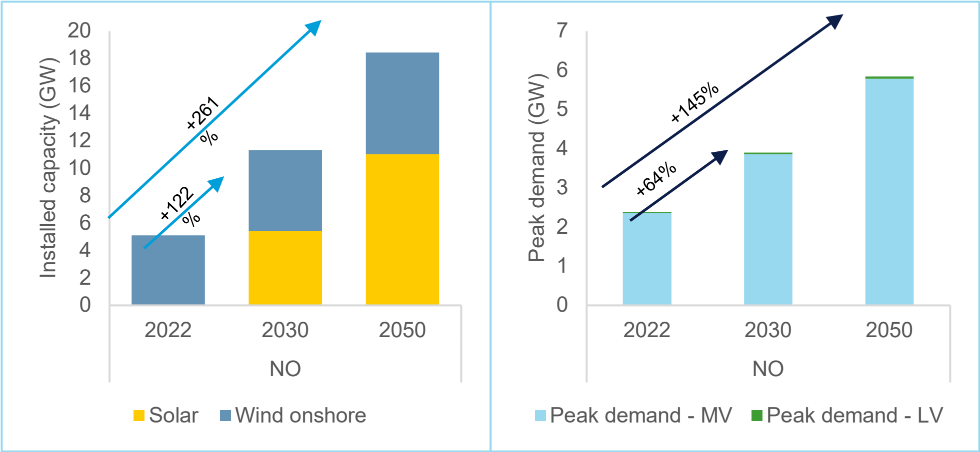
Source: DNV European Power Price Forecast 2023

2.3 RE generation and peak demand is rapidly growing

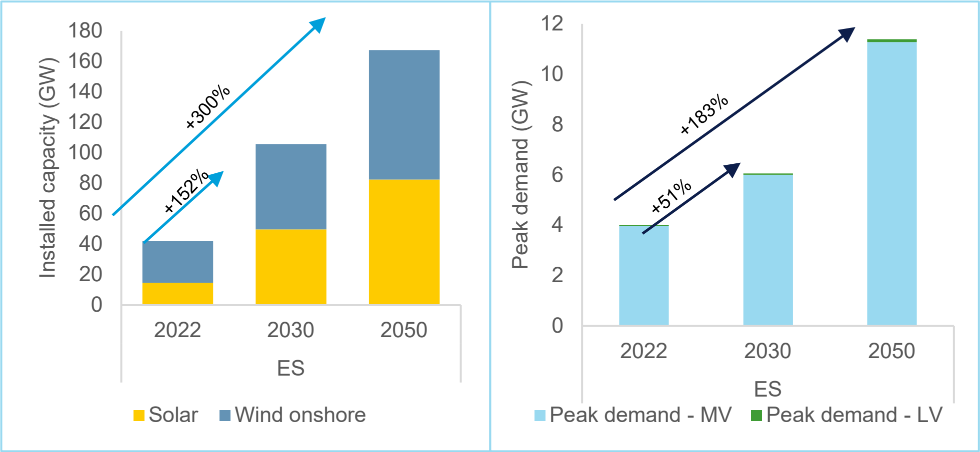
Ireland



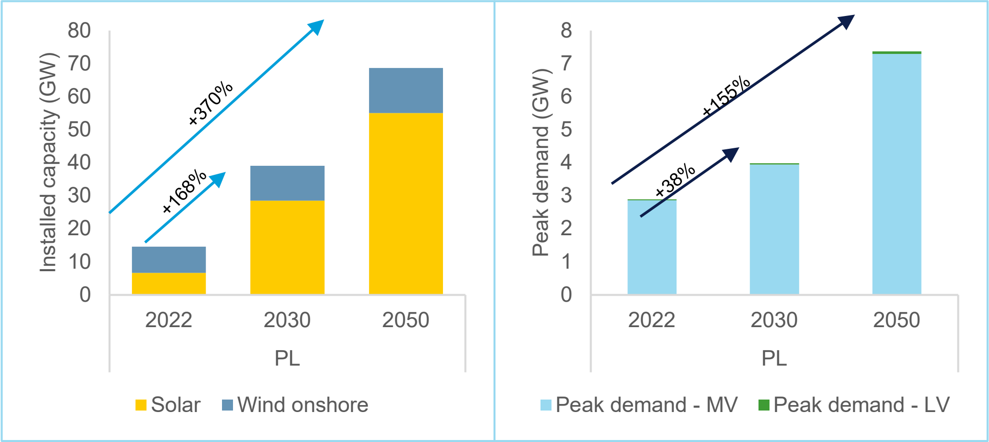
Norway



Spain



Poland



Source: DNV European Power Price Forecast 2023

2.4 What has led to this situation?

The main cause has been insufficient long-term planning

DSOs highlighted insufficient long-term planning as the main reason for network scarcity

DSOs pointed at insufficient holistic long-term planning as the key reasons for network scarcity, as for e.g., governments did not foresee the large demand request from the industry in certain regions, which are now unable to be connected.

The **network is built with a life cycle of 40 years;** therefore, grid investments should aim to ensure appropriate equipment to work for society in that time horizon.

To achieve this, **long-term planning is essential**. DSOs signal that, to be able to make the appropriate grid investments, **governments need to make bold, political decisions** regarding where and which energies technologies (renewables, H2, green gases, etc.) will be developed and where covering a much higher demand will be needed. SOs can aid in these decisions as one of the knowledgeable parties.

E.g., in the NL, the Maasvlakte Energy Hub will develop applications with green H2 and biofuels in that location. The Dutch government has also stated more hubs will be developed in the North Sea beyond 2030.

This **lowers the regulatory uncertainly**, which further incentivises grid investment.

2.4 What has led to this situation?

Other causes of insufficient network capacity

Environmental policies

Environmental policies are at the forefront of European legislation that encourage further renewable integration and decarbonization. To meet climate targets, larger and more grid connections are necessary.

Aging infrastructure

The age of European electricity networks, indicating that over 7 million km of grid lines need to be renewed until 2050 in the EU, due to reaching the end of their life cycle.

Grid resilience

New system complexities and interdependencies within a larger number of actors, together with cybersecurity threats and more extreme meteorological events due to climate change can greatly impact the network capacity needs.

New technology disruption

New technologies connected to DSO level can present an opportunity to DSOs, nonetheless, also a risk of disruption in their network and need for higher capacity; e.g., H2, or Internet of Things (IoT) technologies

2.5 The impact of grid scarcity is significant

Grid capacity is a limited resource that needs to be efficiently managed

1. Inability to connect consumers (demand)

Was ranked as the top impact by the DSOs interviewed, as it **has a direct impact on a country's development and social welfare.**

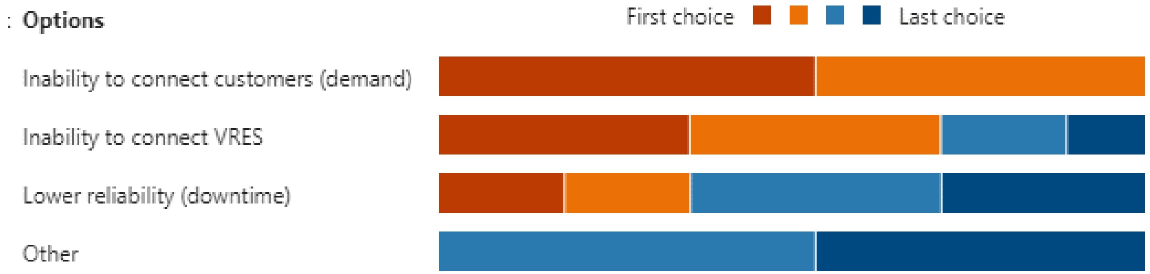
2. Inability to connect variable renewables

Meeting **Increasingly ambitious EU targets** for renewable capacity becomes harder due to grid scarcity.

3. Lower reliability (downtime)

DSOs do not consider compromising reliability. At the moment, it is not impacted as, for example, the connections allowed are being limited. Nonetheless, a DSO did share that currently operations are riskier than before, for example, when a planned outage is needed for grid maintenance or reinforcement, and that there is now more flicker.

DSOs ranked inability to connect customers as the main impact of network scarcity



+ Other – Grid capacity cannot be taken for granted:

Some DSOs highlighted as one of the main impacts, that there was **now a need to disconnect customers** or limit their connections.

There is a need to shift from the 'fit and forget' approach to **a new understanding that grid capacity is a limited resource that needs to be efficiently managed and optimised.**

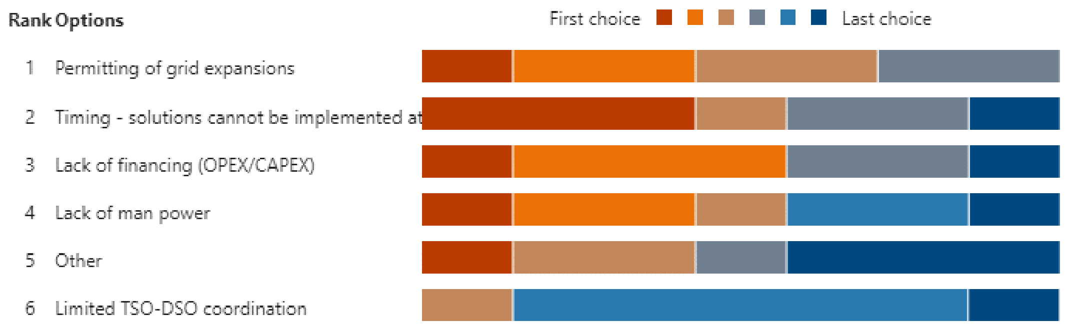
2.6 Current four key drivers of grid scarcity

Grid reinforcements alone are insufficient

Massive grid reinforcements are needed, but this mechanism alone cannot solve grid scarcity. The main causes for this were ranked by DSOs:

1. Permitting /Timing	The process requires many interactions and takes too long. E.g., a DSO in Germany as of October 2023, has had none of their permitting requests approved since 2017.
2. Financing	In some Member States there is not enough financing to invest in the reinforcements needed.
3. Lack of manpower	There is not sufficient skilled workforce to implement the grid reinfocements necessary.
4. Limited TSO-DSO coordination	Not considered one of the main causes. There is satisfactory coordination within SOs, some DSOs looking to expand it during real time operation.

Permitting of grid expansions is listed as the top cause



+ **Other – Regulatory incentives and readiness:** Several DSOs pointed at a lack of regulatory incentives to encourage investment in networks as the main cause for network scarcity. As a regulated business, the regulated level of investment and return depends on regulation.
+ **Other – Supply chain:** High demand, especially for transformers, that e.g., in Norway might take two years to supply, this timing having to be anticipated or lack of equipment availability.
+ **Other – R&D and digitalisation**: with not enough investment in smart grid solutions and digitalisation.

3. Solutions – Flexibility in the DSO grid

Index 3. Solutions – Flexibility in the DSO grid

- 3.1 Solution space focuses on demand side flexibility
- 3.2 DSOs shall develop their capabilities
- 3.3 Purpose for flexibility in DSO grid is clear
- 3.4 Main grid capacity management solutions
- 3.5 A flexible energy system as the key lever
- 3.6 Main demand-side flexibility solutions
- 3.7 DSO maturity steps (1/2)

3.1 Solution space focuses on demand side flexibility

Overview of the solution space

- An overview of the solution space is depicted below. Grid reinforcements alone will be insufficient to address the grid scarcity challenge, hence we present three other **solution types**: Demand side flexibility (DSF), technical solutions and N-1 smart operation (only relevant for HV grids).
- This project focuses on DSF and could be classified in four **groups**: 1. Connection Agreements, 2. Network tariffs, 3. Market-based procurement and 4. Rules-based approach.
- DNV discussed these four groups with European DSOs, which used within each category the following **mechanisms**: 1. Deep connection and non-firm connection agreements, 2. ToU tariffs, 3. Flexibility Markets and RECs/CECs. The rules-based procurement was not widely discussed.

Solution type	Demand Side Flexibility						Technical solutions	N-1 smart operation	Grid reinforcement
Group	Connection agreements		Network tariffs	Market-based procurement		Rules-based approach			
Mechanism	Deep connection agreement	Non-firm connection agreement	ToU tariffs	Flexibility markets	RECs and CECs	Rules-based approach			

3.2 DSOs shall develop their capabilities

There is a growing need for DSO grids to be actively managed

- The **gap** between the **network available capacity** and **network needed** for the connection of RES and electrified loads continues to widen.
- To bridge this gap, **DSOs need to develop their capabilities to operate a more active network.**
- The DSO capabilities that need to be further developed are summarised in the table.
  - With more assets connected at DSO level, the **core DSO activities** performed to date such as network operation and investment planning **are becoming more complex.**
  - Furthermore, **new activities need to be performed** to address the new system needs.
  - One of the new capabilities that needs to be developed is the **management of the flexibility of its grid, acting as a service/market facilitator.**

	Capabilities	Description
1.	System Coordination	Coordination with other networks and systems on planning and operation across different timescales.
2.	Network operation	Ensure power flows remain within acceptable levels. Ensure a safe and secure system managing risks.
3.	Investment planning	Evaluate network capacity requirements and secure the most efficient means to cover it.
4.	Connection & connection rights	Provide fair DSO network access with connection options to meet customer and system needs.
5.	System defence and restoration	Flexible services to ensure system security, for high impact, low probability events and outage restoration.
6.	Service/ market facilitation	Enable capacity products, flexibility/local markets/services and auctions and provide the information/control services needed.
7.	System optimisation	Provide network access to additional flex services and optimise the whole system through the selection of flexibility services across timescales.
8.	Charging	Sets Distribution Use of System prices and other charges.

DSOs capabilities to be further developed. Source: ENA DSO Roadmap (Energy Networks Association, 2018)

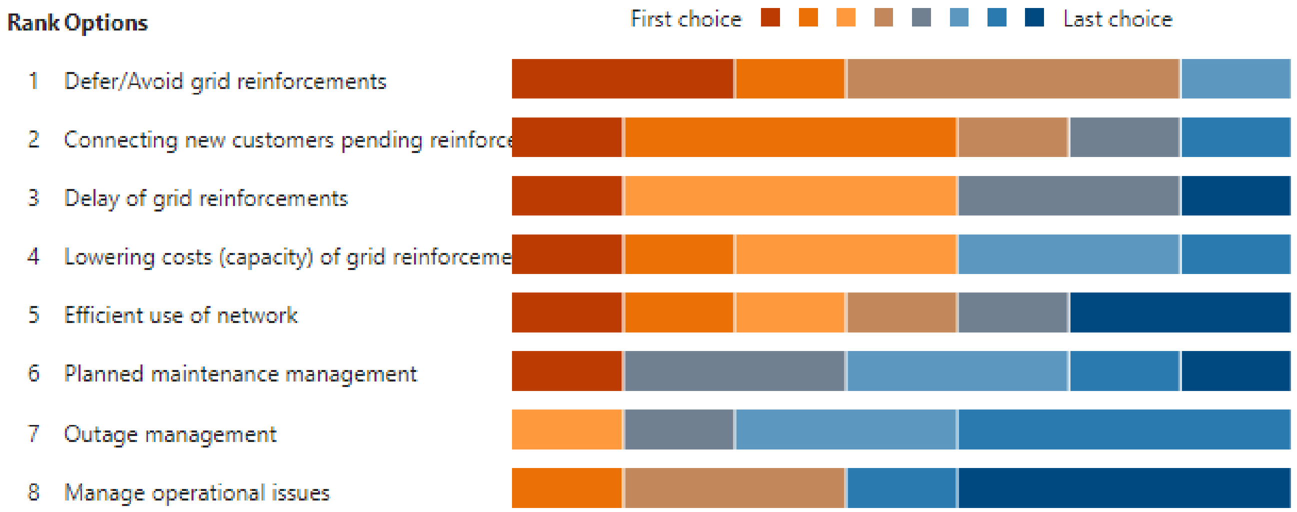
3.3 Purpose for flexibility in DSO grid is clear

The value of flexibility depends on the reason why it is implemented

- Different purposes for which flexibility schemes can be implemented are ranked by the DSOs.
- **The value of the flexibility mechanisms depends on the purpose for which it is implemented (in severity and urgency).** I.e., if it solves a very urgent and sever issue, the mechanism holds more value.
- Most DSOs have **not quantified the contribution of flexibility for each of the different purposes.** This is a crucial step for DSO development and overall system optimisation.

1. Avoidance of grid reinforcement
2. Connecting customers pending grid reinforcements
3. Delay of grid reinforcement
4. Lowering costs (capacity) of grid reinforcements
5. Efficient use of the grid
6. Planned maintenance management
7. Outage management
8. Manage operational issues

From the DSOs interviewed, 4/7 have not yet quantified the flexibility potential for the different purposes



3.4 Main grid capacity management solutions

Focus will be on demand side flexibility (DSF)

- In addition to grid reinforcements, an array of solutions for grid capacity management will need to be optimised for DSOs to plan their efforts and investments efficiently and in time. **Grid capacity management solutions** can be classified as follows, categories not necessarily being mutually exclusive.
- **Flexible solutions** are mechanisms that enable the adjustment of generation or demand to achieve a balanced and efficient energy system. **The focus of this project will be on demand side flexibility solutions**

Grid reinforcements

- Upgrading network assets or adding new ones to increase the capacity of the grid.
- If implemented alone, the solution is insufficient to address current network challenges and meet decarbonisation and RE integration targets.

Demand Side Flexibility

- DSF is defined as the **ability of active consumers to change their consumption and generation patterns based on external signals** (USEF, 2021).
- It can be explicit (e.g., flexibility market) or implicit (e.g., network tariffs).

Technical solutions

- Technical solutions involving optimising the use of the assets or improving their capabilities.
- For example, the optimisation of the operational performance of an asset or dynamic asset rating.

N-1 smart operation

- Only for high voltage
- This could be done permanently, moving from redundancy in assets to more intelligent operation, or
- Temporarily, by allowing not having N-1 for a few hours a year for specific reasons such as maintenance.

3.5 A flexible energy system as the key lever

Demand side flexibility will be *permanent* and contribute *substantially* to solving capacity constraints

7/7 DSOs agreed flexible solutions will *substantially* contribute to address limited grid capacity

7/7 DSOs consider flexibility as a *permanent* solution

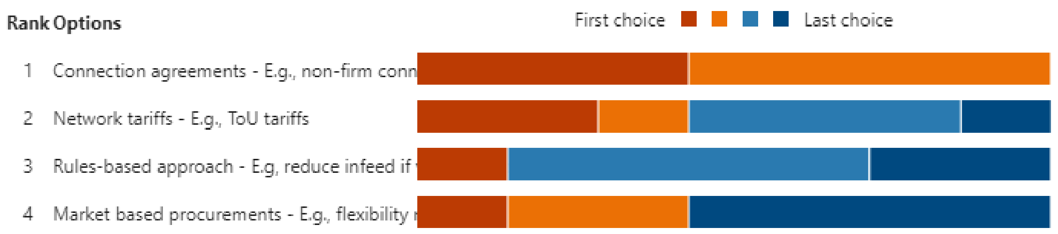
- As we move towards the new reality of an **optimal grid**, we need to assess how to make best use of the capacity available.
- **The Electricity Markets Directive** (EU) 2019/944 also **addresses the need to incentivize flexibility.**

- It is clear that grid reinforcements cannot happen at the speed necessary, therefore**, flexibility will be a necessary solution at the very least for the next decade.**
- **Having established flexibility as a key lever, it is crucial to determine to what extent flexibility can contribute to the energy transition.**

3.6 Main demand-side flexibility solutions

Mechanisms for DSOs to access flexibility

- **CEER classified the demand side flexibility solutions** as shown below, with the categories **not necessarily being mutually exclusive.**
- The options would need to be optimised to implement the solutions that best respond to network needs. The response to the interview question is depicted on the right-hand side.



1. Connection agreement

- In some Member States, DSOs by law need to offer a firm connection to users that can utilise all its contracted capacity whenever needed. With simultaneous RES infeed and growing demand, the risk of exceeding capacity in either directions increases.
- Non-firm connection agreements with lower connection charges is a solution that can maintain network capacity within limits while allowing for new and faster connections without needing to reinforce the grid.
- Not applicable to already-existing users. Discrimination between network users has to be avoided.

2. Network tariffs

- Tariffs designed to encourage network users to have a more network friendly behaviour by exposing them to the network price signals.
- Their effectiveness depends on the users ability to be flexible and the interaction with other price signals.
- They aim at reducing the system and individual peak demand.
- Implicit flexibility provision, as it affects the flexibility then needed by the DSO.
- E.g., dynamic tariffs, that are more advanced and differentiate in time and location.

3. Market-based procurement

- To procure flexibility grid services form the market with bilateral contracts or with a short-term market with enough liquidity (via a platform or interface).
- Market based procurement is on a competitive basis.
- Relatively new phenomenon, with numerous pilot projects and demonstrations. Some countries have implemented it in their BaU operation such as the UK.

4. Rules based approach

- Codes and rules that specify and impose requirements that enhance flexibility.
- The nature of these tends to be technical.
- E.g., reduce infeed if voltage exceeds normal operation level via automatic control.
- Grid-technical measures, including non-costly remedial actions.

3.7 DSO maturity steps (1/2)

All interviewed DSOs indicate to have explored solutions other than grid reinforcement

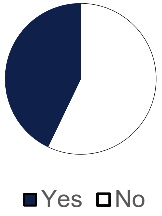
1. Quantifying grid reinforcements

2. Quantifying DSO network grid scarcity

Gap between network available and network needs

3. Explore solutions other than grid reinforcements

4. Quantify potential of flexibility solutions for the different purposes

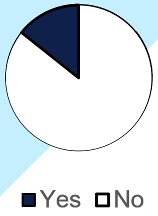


5. Implementation

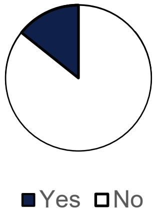
Regulatory

Operations

Organization



6. Optimise those solutions



4. Status of solutions – The DSO perspective

Index 4. Status of solutions – The DSO perspective

- 4.1 Flexibility solutions discussed with DSOs
- 4.2 DSO solution deployment timeline
- 4.3 DSO maturity steps (2/2)
- 4.4 Enedis implemented and optimised flexibility
- 4.5 Internal barriers to flexibility implementation
- 4.6 External barriers to flexibility implementation

4.1 Flexibility solutions discussed with DSOs

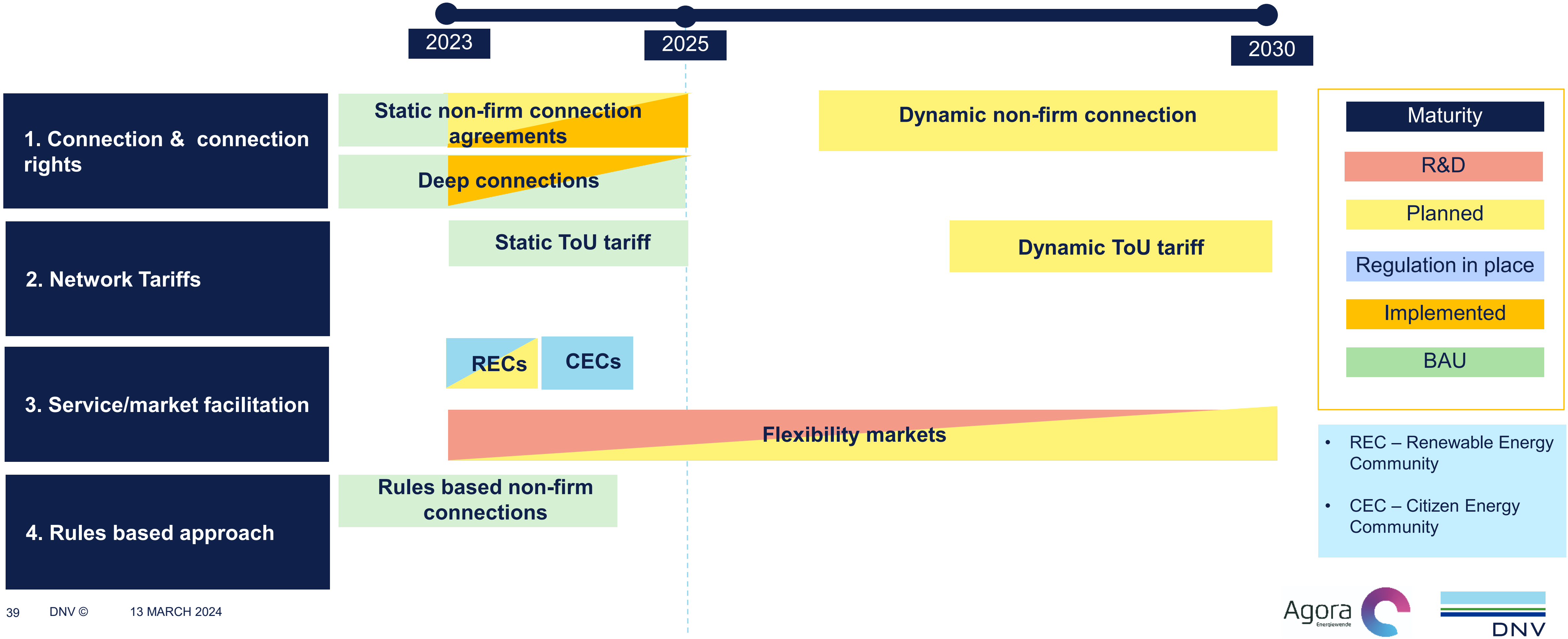
Five solutions were discussed with DSOs and mapped on the timeline with varying maturity

1. Connection agreement	**Static and dynamic non-firm connection agreements**	Defined by CEER as agreements that deviate from the traditional firm connection agreements, for e.g., restricting the customer from using the full capacity under certain conditions (static if conditions remain unchanged, dynamic if they depend on the real-time network limitations).
	Deep connections	Deep connections require the network user to pay the connection costs including the grid reinforcements costs of the needed enlargement or strengthening of the network.
2. Network tariffs	**Static and Dynamic Time of Use (ToU) tariffs**	A time of use tariff (ToU) is a billing structure under which the price for electricity distribution varies depending on the time of the day (e.g., a different price for peak, shoulder and off-peak periods). It is static if the periods remain unchanged, dynamic if they are dependent on real-time network limitations.
3. Market-based procurement	**Renewable and Citizen Energy Communities (REC & CEC)**	REScoop defines energy communities as ‘a way to ‘organise citizens that want to cooperate together in an energy-sector related activity based on open and democratic participation and governance, so that the activity can provide services or other benefits to the members or the local community’.*
	Flexibility markets	Flexibility markets allow the procurement of flexibility at local level by system operators (DSOs and TSOs) for different purposes such as solving congestion management challenges, minimising power outages and postponing grid expansions.

*RECs and CECs are types of energy communities defined in Article 2(16) Recast Renewable Energy Directive and Article 2(11) Recast Internal Electricity Market Directive respectively.
**Rules based approach solutions were not commented on by DSOs.

4.2 DSO solution deployment timeline

DNV discussed with the DSOs the flexibility solutions being assessed and their level of maturity. The four demand side flexibility categories **were ranked in their ability to make the system more flexible**. This integrated overview of solutions, their implementation timeline and their maturity is depicted below and is based on the consolidated response from interviewees (DSOs).



- REC – Renewable Energy Community
- CEC – Citizen Energy Community

4.3 DSO maturity steps (2/2)

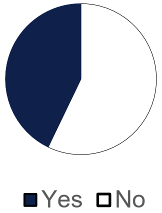
Some DSOs quantify their flexibility potential. Only one DSO has implemented and optimised the flexibility solutions; Enedis

1. Quantifying grid reinforcements

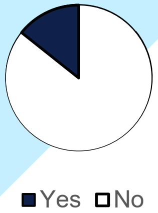
2. Quantifying DSO network grid scarcity
Gap between network available and network needs

3. Explore solutions other than grid reinforcements

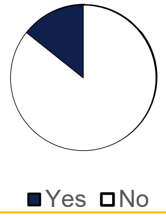
4. Quantify potential of flexibility solutions for the different purposes



5. Implementation
Regulatory
Operations
Organization



6. Optimise those solutions



4.4 Enedis implemented and optimised flexibility

Enedis and its flexibility solutions

- From the DSOs interviewed, Enedis had followed all the defined flexibility implementation steps.
- These included:
  - **1.** quantifying the potential of the flexibility solutions for the different purposes for which these could be applied, and
  - **2.** acknowledging the challenges and risks of limited network capacity, implementing the flexibility solutions listed.
- The three main mechanisms to enhance flexibility are summarised on this slide. In addition, a 4-year trial is being conducted since 2021, explained in the next slide.
- All details are explained in the 2023 Network development plan from Enedis.
- The aim is to optimise the grid and be able to connect the renewable generation and electrified loads such as electric vehicles.

Investment optimisation

- Since 2021, Enedis systematically analyses whether there is any flexibility solution that could allow a planned grid investment **due to excess generation or consumption** to be postponed.
- Aim is to postpone the investment if flexibility 'beats' the economic performance of the planned investments.
- To date, these cases have been limited.

Alternative connection offer

- Enedis, by law, must offer a connection that always ensures availability of the power line.
- Since 2020, producers can request an alternative connection offer with power modulation, **whose guaranteed injection power is lower than the requested connection power.**
- Since no network adaptation work is required, the connection is faster and less costly for the producer. However, it can be capped without financial compensation within set limits.

Time of use tariff

- Provides the incentive to customers to shift, aiming to **solve most EV charging difficulties**.
- It is designed to have both an energy-based and a power-based component.
- It has three seasonal periods.
- In France, network users connected to 400kV are not exposed to these tariffs (this voltage level is not considered to be the main cost driver.)

4.4 Enedis implemented and optimised flexibility

The Enedis REFLEX project explained

- The REFLEX project allows **more generating facilities to be connected to a single source substation transformer**. In turn, it resorts to **punctual production limitations**.
  - The aim is to test flexibility called on the market, competing with capping production, that would be the fall-back option in case of an unsuccessful tender.
  - Curtailment is expected to account for no more than **0.06%** of the energy generated by new facilities connected to the grid and producers would be compensated.
- The assets are then used more often at their maximum capacity. The project translates into **210MW increase in capacity for 10 source substations** involved in the trial.
- The trial is operating under a regulatory sandbox **since 2021 and is planned to last four years**.
- It is expected to **bring 250 MEUR savings to the community by 2035** (300 MEUR in savings minus 50 MEUR of energy not injected).
- At the national level, **the work required to accommodate all RES installations could be reduced by 30% between now and 2035**.
- **2.5GW** could be made available in the short term.

Simulated increase in capacity (in %) due to flexibility provided by REFLEX.

Source: Enedis Plan de développement de réseau 2023

4.5 Internal barriers to flexibility implementation

1. Unknown flexibility potential

- Need for **visibility of the flexibility potential** of the alternative solutions

2. Grid observability

- **Currently full observability achieved at HV level**, MV grid having elements that enable some observability, and **LV observability being low**
- Granularity at MV and LV, with high penetration of smart meters is necessary for a better view of grid flows

3. Transition to more active grid management.

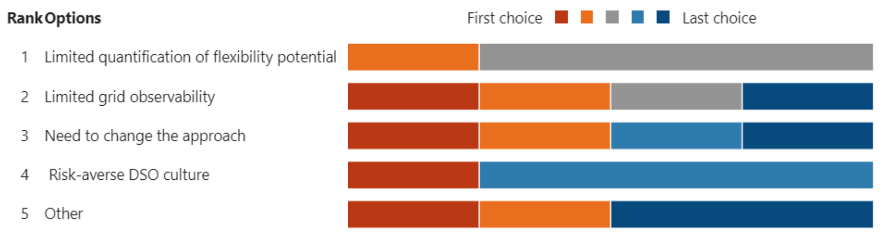
- DSO traditionally operated their grid in a fit-and-forget strategy
- Using flexibility requires active system management, which will be a **structural change to the organisation, competences** etc.

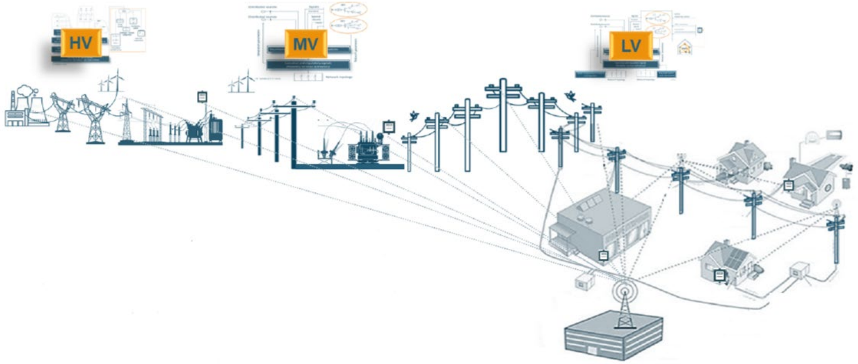
4. Risk averse DSO culture

- Typically **preferring hardware-based solutions over** solutions relying on market parties
- Preference for simplicity over complex (highly automated) system

5. Other - IT and system automation and its cost

- Assets data bases need **advanced data management and communication systems**
- Making the grid smart and **operating/ maintaining the smartness is costly and needs specialised workforce to drive/implement these changes**





4.6 External barriers to flexibility implementation

Type of external barrier	Explanation
1. Regulatory framework	• The provisions of the Electricity Market Regulation and Directive should be transposed into national laws swiftly. • E.g., lack of regulatory framework for non-firm connection agreements in some countries. • The regulatory framework should incentivise and enable flexibility solutions. With regards to the regulatory model, it is relevant how opex and capex allowances are set. Some regulators moved to a totex regulatory model, which provides DSOs with the freedom to deliver set outputs as they see fit, subject to an overall total expenditure allowance. Regulators could also consider to introduce an explicit financial incentive for flexibility.
2. DSO financial incentives	• DSOs need proper incentives to move from CAPEX-based solutions (grid reinforcements) to OPEX-based solutions • Cost benefit analysis needs to be positive
3. Business case for market parties	• May seem unattractive if volumes are (too) small and it requires a fundamental different business model / IT system / customer approach.
4. Customer participation **Business case for end users**	• There could be limited appetite for customers to participate in flexibility services. • This partly relates to the business case, but also to unfamiliarity with the concept and lack of understanding of cost and benefits related to flexibility, • Also, customers may keep the flexibility to themselves.
5. Aggregator role further development	• The aggregator role is not sufficiently developed to utilise flexibility from smaller grid-users (for example household customers). • Aggregators are a key enabler for large-scale utilisation of local flexibility markets
6. Vested interests of incumbents	• E.g., generators seeing dynamic non-firm connection agreements as a threat to their business.

5. Deep dive selected solutions – Time of Use Tariffs and Connection Agreements

Time of Use tariffs and Non-firm connection agreements
Status quo and barriers

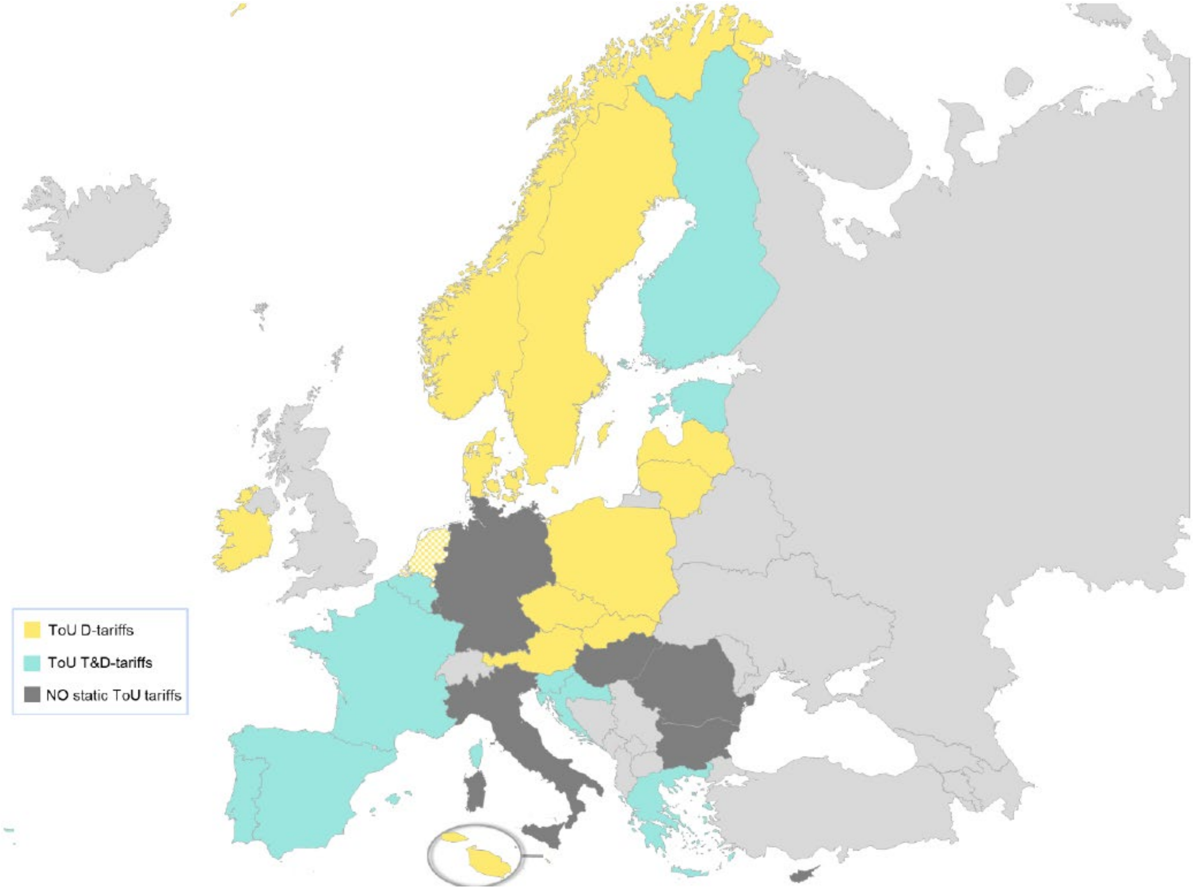
Index 5. Deep dive selected solutions – Time of Use Tariffs and Connection Agreements

- 5.1 ToU grid tariffs in Europe
- 5.2 Barriers: ToU tariffs
- 5.3 Connection agreements in Europe
- 5.4 Barriers: Non-firm connection agreements
- 5.5 Status quo in the selected countries

5.1 ToU grid tariffs in Europe

General overview

- Distribution grid tariffs shall be cost-reflective taking into account the use of the distribution grid by system users including active customers
- Regulation (EU) 2019/943: NRAs shall consider time-differentiated grid tariffs when fixing or approving T&D tariffs or their methodologies
- ToU grid tariffs are charges that vary according to when the service is used (e.g. by peak/off-peak, season, month, weekdays/weekends, hour)
- ToU charges can be static (different time periods are defined well in advance) or they can be more dynamic (e.g. “critical peak pricing”, “real time pricing”)
- Most EU countries apply static ToU distribution tariffs (but the degree of differentiation differs)
- Dynamic tariffs or market-based elements in grid charging (T&D) have been reported for three countries (FR, NO, SE)
- Alternatives or complements to ToU tariffs exist, but are not widely used
- Challenges of the energy transition: develop a pricing structure that provides the right economic signals, considering the challenges for the grid brought by new uses of electricity such as self-generation, energy communities, electric vehicle charging, heat pumps, storage

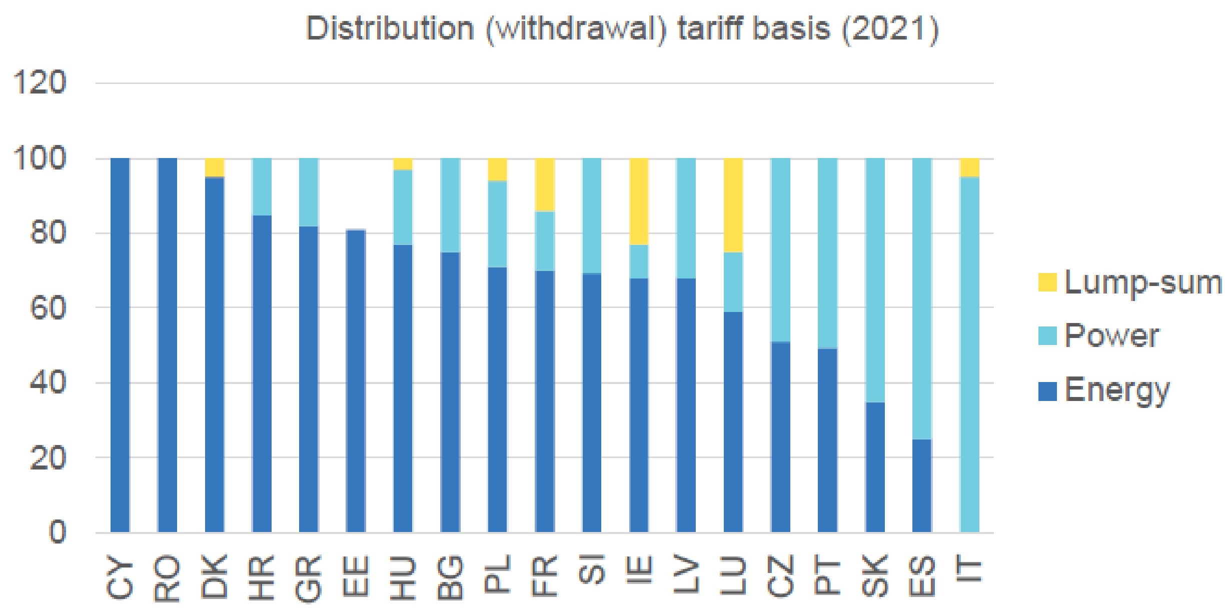


Source: ACER (2023), Report on Electricity Transmission and Distribution Tariff Methodologies in Europe
Note: In the NL, ToU distribution tariffs apply, but to a very limited extent.

5.1 ToU grid tariffs in Europe

Tariff Design

- ToU tariffs can take different forms depending on the basis used for charging:
  - Energy-based: EUR/kWh
  - Power-based: EUR/kW
- About 40% of the EU countries apply the ToU signals for both components and more than half apply the ToU signals only for the energy-based component. One country (GR) applies the ToU signals only for the power-based component.
- Typically, static ToU tariffs vary within-day by defining hours during which a higher or lower unit price is charged for using the grid
- The within-day signals are in many cases divided into 2 periods (day/night or peak/off-peak period), where the periods may range from a few hours up to several hours. However, more than 2 periods within the day are defined in five countries (FR, IE, PT, LV, ES)
- Other differentiations: working-days/ non-working days; seasons
- The ToU signals may be the same to all grid users or they may differentiate among the grid users
- Optional vs. mandatory use of ToU tariffs



Source: ACER (2023), Report on Electricity Transmission and Distribution Tariff Methodologies in Europe

5.1 ToU grid tariffs in Europe

The Spanish Experience

Peak time
Flat period
Off-peak time

- Static ToU tariffs in Spain were implemented on the 1st June 2021 for all electricity consumers (Royal-Decree 148/2021).
- Customers have network tariffs depending on the time period both for energy and power, therefore, the price will depend on when the consumption happens (peak time, flat periods or valley periods).
- Flexibility comes from users being able to adapt their consumption to benefit from reduced prices in certain periods and adapt the power contracted.
- As shown in the diagrams, there is:
    - Different powers can be contracted for each of the two time periods, off peak (00h00-8h00), and peak (8h00-00h00).
    - Consumption is differentiated into three time periods, peak (10h-14h & 18h-22h), flat (8h-10 & 22h-00h) and off-peak (00h - 8h) as well as Saturday, Sundays and national holidays
- The effect of this mechanism to date has been lower than expected.
- This is attributed to the exceptionally steep electricity prices due to the 2022 energy crises being much higher than the grid tariff and the inelasticity of residential consumers without automation.

Figure: Power (upper diagrams), and consumption (lower diagrams) time periods for LV consumers with contracted power below 15kW.

Source: La nueva factura de la luz | CNMC. (2021). Cnmc.es. https://www.cnmc.es/la-nueva-factura-de-la-luz

5.2 Barriers: ToU tariffs

Existing interactions between regulations/ specific regulatory framework and implementation

Regulatory barriers

- Appropriate regulatory framework missing
- Interaction of grid tariffs and retail prices: the economic signal of ToU grid tariffs will overlap with the energy market price and can sometimes point in different directions
- Complexity of implementing ToU grid tariffs may not outweigh the benefits
- A wide implementation of effective ToU tariffs requires periodic adaptation of the time periods

Other barriers

- **Willingness of grid users** to react to ToU signals in the grid tariff
- **Lack of awareness** and understanding from consumers
- Some grid users, e.g. domestic customers, might have a **limited possibility to adjust their consumption** to ToU periods
- **Technical barriers** (e.g. low penetration of meters able to record time of use, no enabling technologies)
- **Complex cost** recording and billing
- **IT developments** require much effort and many resources (e.g., to potentially adopt dynamic ToU tariffs)
- In some cases, the data collection (such as hourly consumption, which is considered personal data) requires **explicit consent** from the customer

5.3 Connection agreements in Europe

General overview

- Connection charges are one-off charges covering the costs (or part of the costs) of connecting new users
- Connection charges may be “shallow” or “deep”, depending on whether a grid user pays only for its own direct connection costs (reinforcement costs are recovered through the use of grid charges paid by all users) or, beyond that, also pays for grid reinforcement
- In EU they are mainly “shallow” or a mix of “deep” and “shallow” connection charges, few instances only “deep”
- For distribution, connection charges are typically pre-determined charges based on voltage level, capacity or distance
- A **flexible** or **interruptible connection agreement** is a contract where the grid user is not guaranteed with a firm connection over the entire period.
- Less than one third of the EU countries reported that they apply such contracts.
- Based on the ACER report (2023), only four countries reported specific rules for setting the grid charge for connected users with this type of contracts (**discounts to the connection or use of grid charges**)

Flexible connection agreements	Implementation options
Customer type	• Old or new connections • Mandatory or voluntary agreements
Allocation of non-firm capacity	• First come, first served • Pro-rata • Market-based
Compensation	• None • Financial: compensation for curtailed supply, connection discount, grid tariff discount • Faster connection
Contract	• Negotiated or standardized • Duration of contract

5.4 Barriers: Non-firm connection agreements

Existing interactions between regulations/ specific regulatory framework and implementation

Regulatory barriers

- Regulatory framework not defined (lack of rules)
- Issues on how to incorporate the new prescriptions into the existing regulatory framework (e.g., non-firm connection agreements vs. traditional solutions).
- Interaction between non-firm connection agreements and market-based procurement of flexibility
  - The EU Directive (Art. 32) prescribes market-based procurement as the primary mechanisms for DSOs to access flexibility.
  - Non-firm connection agreements might lower the liquidity or create market distortions, therefore, CEER recommends their use when flexibility markets are underdeveloped or as a temporary instrument while reinforcements are realised.

Other barriers

- For fully **flexible connection agreements**/ Active Network Management (ANM) in GB terminology – the use of the non-firm connection agreement will depend on the amount of capacity available
- Requires certain **flexibility from system users** – households would not be a target group
- Potential participants need to be able to **predict the curtailment** they might experience before connecting to the grid
- Especially for small distributed generation (DG) users, **increased complexity might** lead to a preference of firm connections

5.5 Status quo in the selected countries

Country	Grid tariffs	Flexible connection agreements
France	• Static ToU distribution tariffs • Daily peak/off peak defined for high and low season • Energy charge is different on each period	• Dynamic non-firm connection agreements • So far limited to renewables • Voluntarily for dedicated assets (customer chooses); plans is to have it mandatory to optimize shared assets
Spain	• Static ToU distribution tariffs • Capacity and energy charge • Domestic tariff: capacity charge has two periods, energy charge has three periods • Other customers have six periods	• Static non-firm connection agreements • Limited to particular agreements with renewables developers where they can feed-in electricity in the grid up to a technical limit • New regulatory framework on non-firm connections is currently ongoing
Norway	• Static ToU distribution tariffs • Residential customers: Load component (kW) based on customers 3 peak hours in the month + energy component • TOU differentiated between day/night/weekend and seasons	• Static non-firm connection agreements • Voluntary both for the DSO and the customer
The Netherlands	• No ToU distribution tariffs (but under discussion)	• Dynamic non-firm connection agreements • Implementation is still limited (only in congested areas and only one type of non-firm capacity) • Voluntary. It can be combined with firm capacity, e.g: 40% firm and 60% non-firm capacity.
Poland	• Static ToU distribution tariffs (these tariffs have been operating for many years)	• No flexible connection agreements

Source: Based on the answers to the survey provided by the DSOs.

6. Findings and key messages – The stakeholder committees

Index 6. Findings and key messages – The stakeholder committees

6.1 DSO challenges and grid scarcity

6.2 Available flexibility solutions

6.3 Flexibility solutions implementation

6.4 Recommendations

6.1 DSO challenges and grid scarcity

Urgent need for addressing grid scarcity

DNV conducted a total of seven interviews with European DSOs, and two stakeholder committee meetings. The first stakeholder committee meeting included a group of DSO representatives, and the second a wider group with representatives of DG ENER, SMARTEN, ACER, EU DSO Entity, RAP and Agora Energiewende. This Section highlights the key messages discussed during these meetings, as well as the key messages extracted by DNV.

- All stakeholders acknowledge that grid capacity limitations are an issue that is only becoming more challenging with time and, if not addressed urgently, will become a main bottleneck and act as a barrier to achieve decarbonisation, electrification and renewable integration objectives.
- Various examples were provided of grid scarcity already acting as a barrier, where governments and stakeholders strive to make sustainable investments, for instance, in EV charging infrastructure, but those cannot be realised due to the limitations of the grid.
- With other prevalent issues (e.g. high electricity prices), electricity network capacity limitations have not gotten the level of priority needed considering its consequences.
- Decision makers are quickly recognizing that for more renewable integration, augmenting grid capacity is necessary. Regulations need to be adapted to accommodate for this. For instance, incentive regulation needs to be enhanced to make sure DSOs consider flexibility as an alternative to investments. In addition, the use of flexibility services by distribution utilities may also be encouraged by a more cost reflective tariff structure, such as tariffs for the use of the networks and connection charges.
- Grid reinforcements traditionally alleviated grid capacity scarcity. Insufficient long-term planning and a lack of proper incentives have led to insufficient reinforcements in the past years. Currently, long permitting processes and insufficient workforce and incentives make this solution alone insufficient to address the challenge given the urgency.
- Massive investment in network reinforcements is still needed. Nonetheless, even implementing the maximum grid reinforcements possible considering the time and workforce available**, other solutions are essential to solve congestion in a timeline (and budget) that fits with the decarbonisation ambitions.**
- Stakeholders stress that it is not either/or; and understand that **multiple solutions are necessary and not competing.**

6.2 Available flexibility solutions

Accelerating support for flexible solutions in power grids is needed

- DSOs are unable to keep up with the pace that is necessary to implement alternative solutions (technical or demand based) in time to meet environmental targets, as it takes significant time (to update regulation, retrofit substations, etc.). The question remains whether DSOs will be able to implement these solutions in time.
- **Identifying and removing the barriers** (regulatory, market, organisational, technical) for a quick implementation of alternative solutions should be **prioritised by policy decision makers**. DSOs also highlight the need to access financing for smarter operations that optimise grid capacity.
- Stakeholders consider there is **a need to further involve regulators** in conversations about the severity of this challenge, to potentially encourage a more holistic approach that not only limits network costs, but further fosters innovation.
- **Implementation time of these alternative solutions is crucial.** To take full advantage of market-based flexibility procurement, the development time needs to be shortened. For example, the demand response network code is not expected to be fully implemented before 2030.
- DSOs are showing interest in non-firm connection agreements due to their shorter implementation time and ability to create impact in the short-term.
- There is limited **quantification of the potential of the flexibility solutions for different purposes**, which would be **crucial for optimal and strategic grid planning, operation and investment**. This is a signal that these flexibility solutions are still in their infancy within DSOs.
- Regarding how to best develop the solutions, and which stakeholder should be leading this effort, DSOs tend to wait for regulation to be in place to invest in developing and implementing flexibility solutions.
- On the other hand, policy markers expect it to be more a bottom-up approach and do not further develop regulation as it is not perceived as highly demanded, leading to a circle of limited action.
- **DSOs need to be further encouraged, incentivised and compensated to develop flexible solutions and to lead this effort.**

6.3 Flexibility solutions implementation

Various internal and external barriers to implementing flexibility solutions

- DSOs and market parties need **more certainty to make investments and develop flexibility solutions**. For example, DSOs awaiting the regulatory framework to implement ToU tariffs. Another example would be companies in the Netherlands making sustainable investments in, for instance, an electric boiler, having to then decide whether they want to make an extra investment for flexibility and not being sufficiently incentivized for this additional investment.

- Specific flexibility solutions were also discussed:

- **Non firm connection agreements**: Within European DSOs, this mechanism has different **levels of maturity.** A DSO shared the experience of implementing this solution. Due to a lack of regulatory framework, ‘primitive’ non-firm connection agreements were successfully developed with renewable developers as bilateral agreements to enable the connection. However, to scale up this solution, the support from the regulator would be needed. Regulation in some Member States still indicates that a full connection should be offered. Moreover, non firm connection agreements may not be enough to prevent network congestion or costly reinforcements in some areas. Thus, non firm connection agreements could be complemented with other mechanisms e.g., flexibility markets. Potential interactions between the two solutions need to be assessed by NRAs and DSOs.

- **Grid tariffs:** The effectiveness of the tariffs will depend on **1. a clear price signal that exceeds the energy price signal when/where needed 2. the level of automation** of smart energy management systems and **3. presence of assets with inherent flexibility** (EV chargers, heat pumps, batteries, etc.). In Spain, **static ToU grid tariffs were mandated,** with the effect of this mechanism to date being lower than expected. This is attributed to the electricity prices being much higher than the grid tariff and the inelasticity of residential consumers without automation. Some DSOs are skeptical about implementing **dynamic grid tariffs.** This is due to increased complexity, lack of tariff predictability, technological requirements and the risk of unfairness. This solution relies on the uncertain reaction of potentially responsive network users; therefore, it is important to properly inform consumers.

- **Flexibility markets:** The potential of further smart meter roll out is necessary, the regulatory framework needs to be developed or there need to be more effective incentives for participation. It is at a **lower maturity level** than non-firm connection agreements and grid tariffs. In some countries, **Parties' investment interest in flexibility markets depends on whether there is long-term certainty, which is currently not there.** As the costs of contracted flexibility are typically recovered through the distribution tariffs, regulation should promote the use of flexibility when it is the most cost-efficient option, as stated in the Electricity Market Design Directive.

6.4 Recommendations

Accelerating the implementation time of DSF mechanisms is essential as, having assessed the maturity of the different solutions and their potential implementation timelines, there are questions whether DSOs can implement the solutions in time to avoid scarce grid capacity being a bottleneck for the energy transition. To do so, DNV recommends:

- To incentivise DSOs to significantly accelerate the implementation and deployment of flexibility solutions by (1) continue to quantify the capacity scarcity, (2) quantify the potential of each flexibility solution for the different purposes for which it can be implemented (3) formulate a strategy to implement the relevant solutions within a certain timeline. This will enable optimal and strategic longer-term planning, operation and investment.
- Encouraging, incentivising and compensating the DSOs to develop these solutions, empowering them to lead this effort. To date, DSOs tend to await regulation to be in place to invest in developing and implementing flexibility solutions. This is because DSOs and companies need long-term certainty to make the investments in flexible solutions. DNV recommends providing further certainty with for e.g., regulatory commitments and longer-term planning.
- Regulators developing the regulatory frameworks, not only to assess DSOs on reliability and affordability, but also on sustainability, allowing an appropriate return of investment for DSOs that are able to connect a higher share of renewables. Regulators should also further stimulate customers to unlock their flexibility.
- To ensure the speedy transposition of the European regulations such as the EU revised Electricity Market Regulation and Directive is key. A monitoring report published by SmartEn shows that more than 20 articles of the Electricity Regulation and Directive (related to flexibility) are far from being implemented. Other more recent reports (such as ACER, 2023 and SmartEn 2023) also show that a proper legal framework is a pre-condition to unlock flexibility.

A.1: Appendix 1

References

Appendix 1

Key References

#	Reference
1	Council of European Energy Regulators, & Distribution Systems Working Group. (2020, July 16). CEER Paper on DSO Procedures of Procurement of Flexibility. Retrieved from https://www.ceer.eu/documents/104400/-/-/e436ca7f-a0df-addb-c1de-5a3a5e4fc22b
2	Council of European Energy Regulators. (2018, July). Distribution Systems Working Group; Flexibility Use at Distribution Level - A CEER Conclusions Paper. Retrieved from https://www.ceer.eu/documents/104400/-/-/e5186abe-67eb-4bb5-1eb2-2237e1997bbc
3	Deloitte; E.DSO; eurelectric . (2021, January). Connecting the dots: Distribution grid investment to power the energy transition. Retrieved from https://www.edsoforsmartgrids.eu/images/publications/connecting-the-dots-full-study-h-AE5C8724.pdf
4	Enedis . (2023). Retrieved from Plan de développement de réseau: https://www.enedis.fr/sites/default/files/documents/pdf/plan-de-developpement-de-reseau-document-preliminaire-2023.pdf
5	Energy Networks Association. (2018). DSO Functional and System Requirements ON-WS3-P2.
6	ETIP SNET. (2022). Flexibility for Resilience; How can flexibility support power grids resilience? Retrieved from European Technology and Innovation Platform Smart Networks for Energy Transition - Fuchs, A., Ilo, A., Yaman Evrenosoglu, C., Dikaiakos, C., Mataczynska, E., Migliavacca, G., Kamsamrong, J., de Souza Silva, N., Divshali, P., Porwal, R., Gallego, S., & De: https://op.europa.eu/en/publication-detail/-/publication/54d9c702-dc9c-11ec-a534-01aa75ed71a1
7	European Commission . (2022, June 16). Joint Declaration on skills in the clean energy sector. Retrieved from https://commission.europa.eu/system/files/2022-06/ceif_joint_statement_on_skills.pdf IEA . (2022). World Energy Outlook (WEO) 2022. Retrieved from https://www.iea.org/reports/world-energy-outlook-2022
8	IEA . (2022). World Energy Outlook (WEO) 2022. Retrieved from https://www.iea.org/reports/world-energy-outlook-2022
9	Joint Reserch Centre . (2023). Meletiou, A., Vasiljevska, J., Prettico, G., & Vitiello, S. (2023). Distribution System Operator Observatory 2022; Managing innovation and RES grid connection for a carbon-neutral Europe. JRC Science for Policy Report . https://doi.org/10.2760/778963
10	La nueva factura de la luz | CNMC. (2021). Cnmc.es. https://www.cnmc.es/la-nueva-factura-de-la-luz
11	Mataczyńska, E., Rodríguez, J. M., Heijden, S. v., Kula, J., & Voumvoulakis, M. (2022). E.DSO. Retrieved from Grid observability for Flexibility : https://www.edsoforsmartgrids.eu/images/20220513_TF1_ANM_-_Go4Flex_Report.pdf
12	SmartEN; LCPDelta. (2022, February). 2022 Market Monitor. Retrieved from Demand Side Flexibility : https://smarten.eu/wp-content/uploads/2023/02/DSF-Market-Monitor-2022.pdf
13	Smarten (2023, December). Assessment of the regulatory framework of bidirectional EV charging in Europe. https://smarten.eu/wp-content/uploads/2023/12/V2X-Enablers-and-Barriers-Study_11-2023_DIGITAL.pdf
14	ACER (2023, December 19). Demand response and other distributed energy resources: what barriers are holding them back? https://www.acer.europa.eu/sites/default/files/documents/Publications/ACER_MMR_2023_Barriers_to_demand_response.pdf

A.2: Appendix 2

Glossary

Appendix 2

Glossary

Abbreviation	
ANM	Active Network Management
BaU	Business as Usual
CAPEX	Capital expenditure
CBA	Cost Benefit Analysis
CEC	Citizen Energy Community
CEER	Council for European Energy Regulators
DSO	Distribution system Operator
ENA	Energy Networks Association
EU	European Union
EV	Electric Vehicle
GW	Giga Watt
H2	Hydrogen
HV	High voltage
IoT	Internet of Things
JRC	Joint Research Centre
LCT	Low Carbon Technologies
LTCs	Low Carbon Technologies
LV	Low voltage
M	Million
MS	Member States

Abbreviation	
MV	Medium voltage
NRA	National Regulatory Authority
OPEX	Operational expenditure
R&D	Research and Development
RE	Renewable Energy
REC	Renewable Energy Community
RES	Renewable Energy Sources
SO	System Operator
TOTEX	Total expenditure
ToU	Time of Use
TSO	Transmission System Operator
VRES	Variable Renewable Energy Sources
WP	Work Package

A.3: Appendix 3

Regulatory context

A3.1 Main legislation on the European level

General

- Network Code on Demand Connection (published in August 2016)
- Directive (EU) 2019/944 on common rules for the internal market for electricity (published in June 2019)
- Electricity Regulation (EU) 2019/943 on the internal market for electricity (published in June 2019)
- Proposal for a revised Renewable Energy Directive (proposed in July 2021)
- Network Code on Demand Response (Guidelines submitted by ACER in December 2022)
- Proposal Electricity Market Design Reform (proposed in March 2023)
- Proposal for a revised Energy Efficiency Directive (adopted by Council in July 2023)
- Proposal for Regulation for the Deployment of Alternative Fuels Infrastructure (AFIR) (adopted by Council in July 2023)

A3.1 Main legislation on the European level

General

Legislation	Relevant Articles	Highlights
Directive (EU) 2019/944	• Art. 31: Tasks of distribution system operators • Art. 32: Incentives for the use of flexibility in distribution networks • Art. 59: Duties and powers of the regulatory authorities	• **DSOs shall cooperate with TSOs** for the effective participation of market participants connected to their grid in retail, wholesale and balancing markets • MS shall provide the necessary **regulatory framework** to allow and provide **incentives** to DSOs to procure **flexibility services**, including **congestion management** • DSOs, subject to approval by the regulatory authority, or the regulatory authority itself, shall, in a transparent and participatory process establish the specifications for the **flexibility services procured** and, where appropriate, **standardised market products** for such services at least at national level • The **network development plan** shall provide transparency on the **medium and long-term flexibility services** needed and shall set out the planned investments for the next five-to-ten years
Electricity Regulation (EU) 2019/943	• Art. 3: Principles regarding the operation of electricity markets • Art. 18: Charges for access to networks, use of networks and reinforcement • Art. 55: Tasks of the EU DSO entity • Art. 59: Establishment of network codes • Art. 60: Amendments of network codes • Art. 61: Guidelines	• Distribution tariff methodologies shall provide **incentives to DSOs** for the most cost- efficient operation and development of their networks including through the **procurement of services**. • Regulatory authorities shall recognize relevant costs as eligible, shall include those costs in distribution tariffs, and may introduce performance targets in order to provide **incentives to DSOs** to increase efficiencies in their networks, including through energy efficiency, **flexibility** and the **development of smart grids** and **intelligent metering systems**.
Electricity Market Design Reform (EC Proposal)	• Par. 12, 15, 17, 22, 37, 38, 46 • Art. 19c: Assessment of flexibility needs • Art. 19e: Flexibility support schemes • Art. 19f: Design principles for flexibility support schemes	• **Network tariffs** should incentivise TSOs and DSOs to use **flexibility services** through further developing **innovative solutions** to optimise the existing grid and to procure flexibility services, in particular **demand response** or **storage**. • This would further contribute to integrating renewables at the least cost for the electricity system and enable final customers to value their **flexibility solutions**. • Regulatory authorities should periodically assess the **need for flexibility** in the electricity system based on the input of TSOs and DSOs. The assessment of the flexibility needs of the electricity system should take into account all existing and planned investments on sources of flexibility such as **flexible electricity generation, interconnectors, demand side response, energy storage** or the **production of renewable fuels**, in view of the need to decarbonise the energy system.

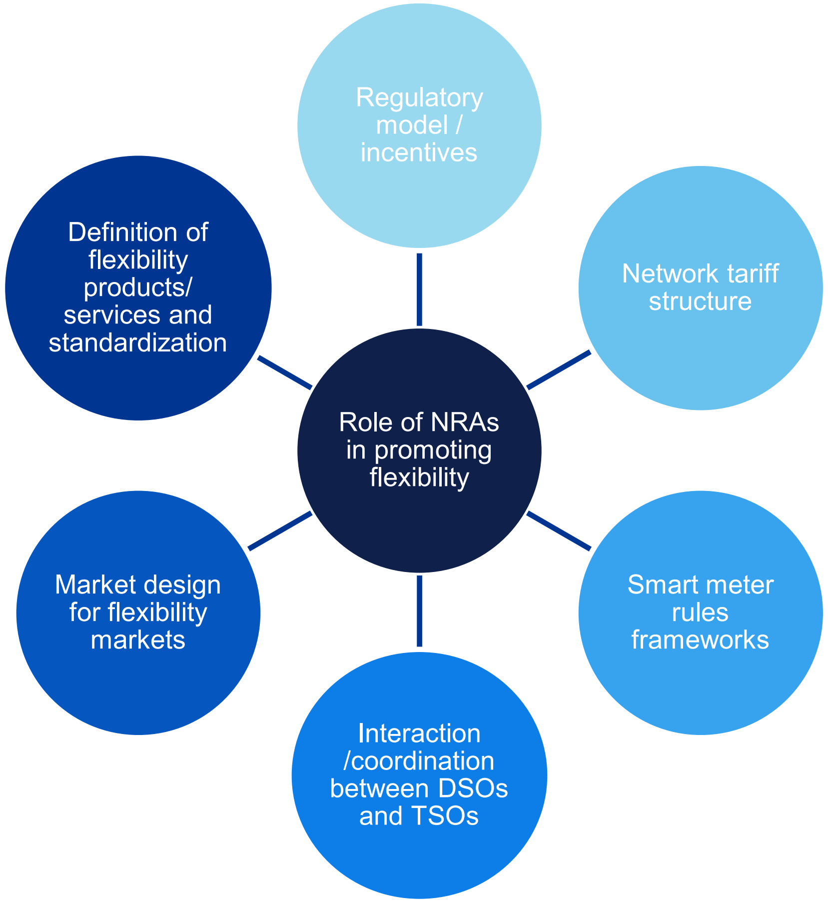
A3.1 Main legislation on the European level

General

Legislation	Relevant Articles	Highlights
Proposal for a revised Renewable Energy Directive	• Par. 5, 18, 19 • Art. 20a: Facilitating system integration of renewable electricity	• The proposal for a revised Renewable Energy Directive, reiterates the importance of having national regulatory frameworks, which "do not discriminate against participation in the electricity markets, including **congestion management** and the provision of **flexibility and balancing services, of small or mobile systems** such as **domestic batteries and electric vehicles**, both directly and through **aggregation**.
Proposal for a revised Energy Efficiency Directive	• Par. 19 • Art. 27: Energy transformation, transmission and distribution	• The proposal for a revised Energy Efficiency Directive strengthens the value of **demand-side flexibility** in view of the energy efficiency first principle and calls MS 'to take into account potential benefits from **demand-side flexibility** in applying the energy efficiency first principle and where relevant consider demand response at both centralised and decentralised level, **energy storage**, and smart solutions as part of their efforts to increase efficiency of the integrated energy system.'
Proposal for Regulation for the Deployment of Alternative Fuels Infrastructure (AFIR)	• Par. 14, 58 • Art. 14: National policy frameworks • Art 15: National reporting	• The proposal for Regulation for the Deployment of Alternative Fuels Infrastructure (AFIR) sets mandatory infrastructure targets for the **electric vehicle** (EV) fleet which will be primarily connected at distribution level. • The proposal empowers National Regulatory Authorities to assess the '**contribution of EVs to the flexibility of the energy system**'.
Network Code on Demand Response	• Ch. 2: General requirements for market access • Ch. 5: Congestion management • Ch. 6: Voltage control	• On 1st June 2022, the ACER has been asked by the EC to submit non-binding framework guidelines setting out clear and objective principles for the development of a network code on demand response. • The network code will aim at enabling **market access for demand response, including load, storage and distributed generation** (aggregated or not), as well at facilitating the **market-based procurement of services** by DSOs and TSOs. *Process:* *1. ACER submits non-binding framework guidelines (subject to public consultation)* *2. EU DSO Entity and ENTSO-E drafts Proposal for a Network Code on Demand Response* *3. ACER reviews it and submits to EC*
Network Code on Demand Connection	• Par. 8	• **Demand response** is an important instrument for increasing the flexibility of the internal energy market and for enabling optimal use of networks. • It should be based on customers' actions or on their agreement for a third party to take action on their behalf. • A demand facility owner or a closed DSO may offer **demand response services** to the market as well as to system operators for grid security.

A3.2 Role of National Regulatory Authorities (NRAs) in promoting flexibility

- **The regulatory model/ incentives** may influence DSO's preferences between the use of traditional solutions (i.e., reinforcement), flexible solutions or a combination
- **The use of flexibility services** by DSO may be encouraged by a more cost reflective tariff structure, such as tariffs for the use of the networks and connection charges
- **The use of standardized definitions** of flexibility products or services may help to promote flexibility services, facilitate the development of markets with more participants
- **NRAs can play an important role** in specifying the market design for flexibility markets
- **Smart meters are enablers** of unlocking flexibility resources within the distribution system. NRAs may need to change the rules framework for smart meters to fully exploit the potential of flexibility arising from the existence and use of smart meters
- **Managing and procuring flexibility** to solve network constraints, congestion, etc., requires more active networks and more coordination between network operators (i.e., DSOs and TSOs). This coordination can be encouraged via regulation.



A3.3 Main legislation on the National level

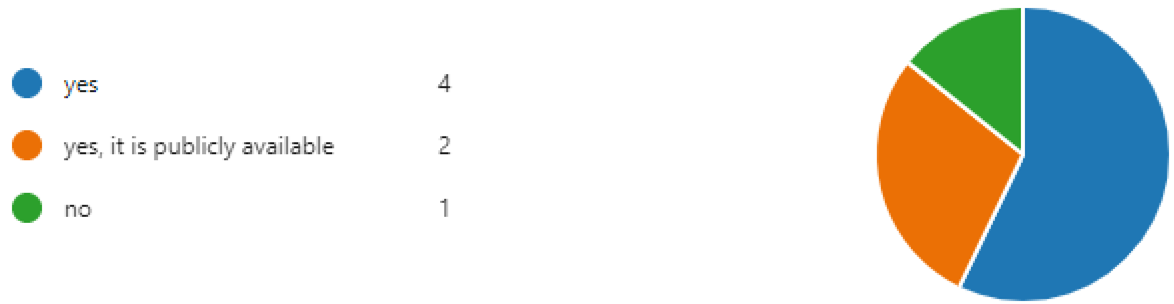
- **Regulatory Model / Incentives**
- The regulatory model may influence DSOs' preferences between the use of traditional solutions (i.e., reinforcement), flexible solutions or a combination of the two.
- Flexibility services are operating expenditures (OPEX), and DSOs typically have efficiency benchmarks for OPEX with rewards if they outperform their OPEX baseline and penalties if they underperform.
- When DSOs use flexibility as an alternative to distribution grid investments, OPEX (cost of flexibility services) increase and capital costs decrease, negatively impacting their efficiency benchmarks and return on investments.
- Typically, incentive regulation is the mechanism used to regulate distribution networks (via a revenue or price cap), but different levels of complexity may apply
- The TOTEX approach (which provides the freedom to select either OPEX or CAPEX to meet network demands) looks "superior" to non-TOTEX approaches, which may bias network expenditure towards CAPEX or OPEX based solutions.

Country	Treatment of OPEX and CAPEX	Specific incentive mechanism for flexibility
France	• OPEX subject to auditor analysis, CAPEX based on actual spendings (bonus/penalty applies based on reference unit cost model • TOTEX for 'non-grid' investments (i.e., real-estate, vehicles and information systems)	No
Spain	• OPEX based on reference values and subject to efficiency factor • CAPEX based on investment reference values	No
Norway	• Applies total cost benchmarking • Total costs consist of the OPEX, cost of energy not supplied (CENS), return on assets, depreciation and cost of network losses	No
Ireland	• OPEX and CAPEX treated differently • Base-trend-step OPEX analysis • Unit cost assessment for CAPEX	Yes flexibility mechanism that provide the DSO with the ability to move revenues from CAPEX to OPEX
The Netherlands	• Yardstick competition • yardsticks equal to the average cost per unit of output, based on the actual cost of the DSOs	No
Germany	• Applies total cost benchmarking	No

A.4: Appendix 4

Response interviews

Question 1: Has your DSO quantified the level of grid reinforcements needed?



Question 2: Is your DSO currently facing insufficient network capacity issues [per voltage level and cause of capacity limitation]? [multiple answers possible]

- **Voltage** - LV is below 1kV and MV between 1-37kV
- **Feed in** of generation, particularly renewables; **off-take** meaning of demand, for instance due to large electrified loads.

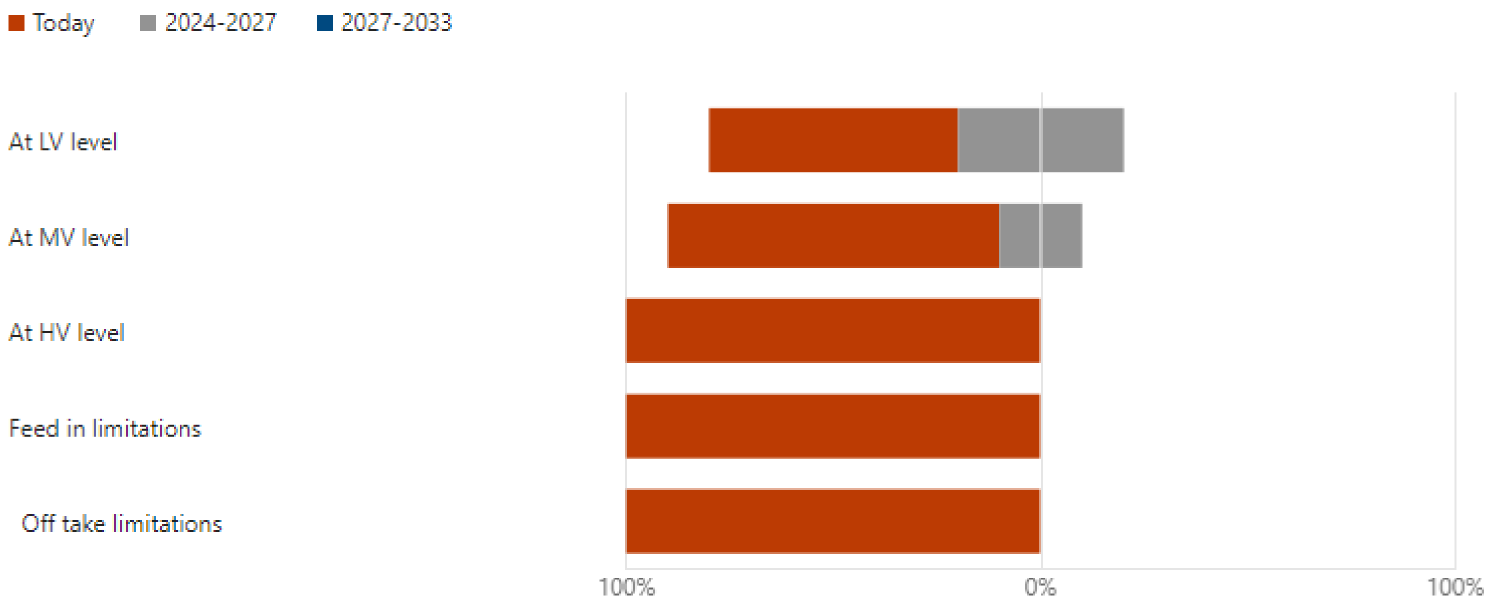
More Details

Yes, at LV level	4
Yes, at MV level	5
Yes, feed in grid limitations	6
Yes, off-take grid limitations	6
No	1

Question 3: If ever, by when do you expect a insufficient network capacity challenge in the future [per voltage level and cause of capacity limitation]?

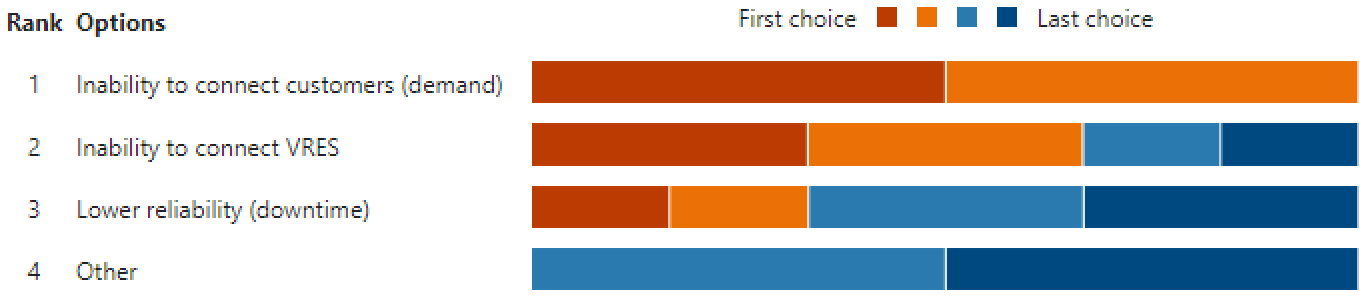
- Voltage indications - LV is below 1kV and MV between 1-37kV
- Feed in of generation, particularly renewables; off-take meaning of demand, for instance due to large electrified loads.

More Details

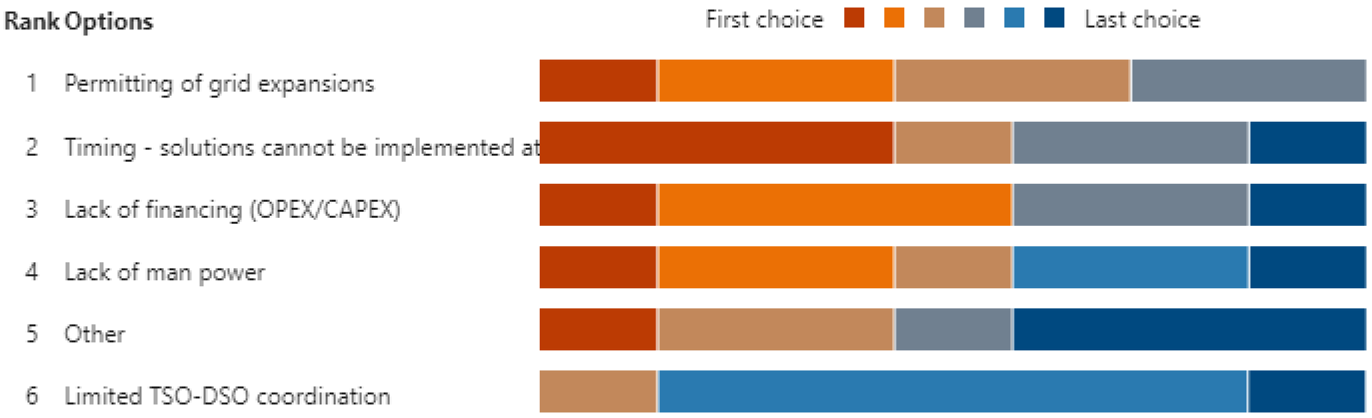


Question 4: Has your DSO quantified the network capacity limitations?

Question 5: What is the main impact if the insufficient network capacity cannot be avoided or removed? [please rank]



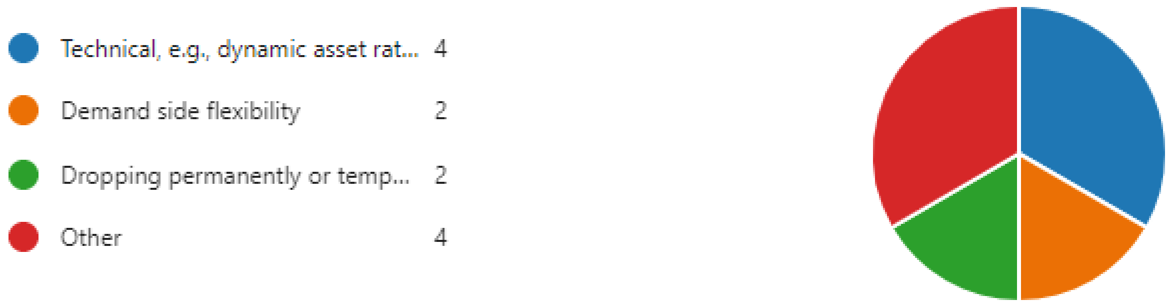
Question 6: Please rank. What are the main causes for insufficient network capacity?



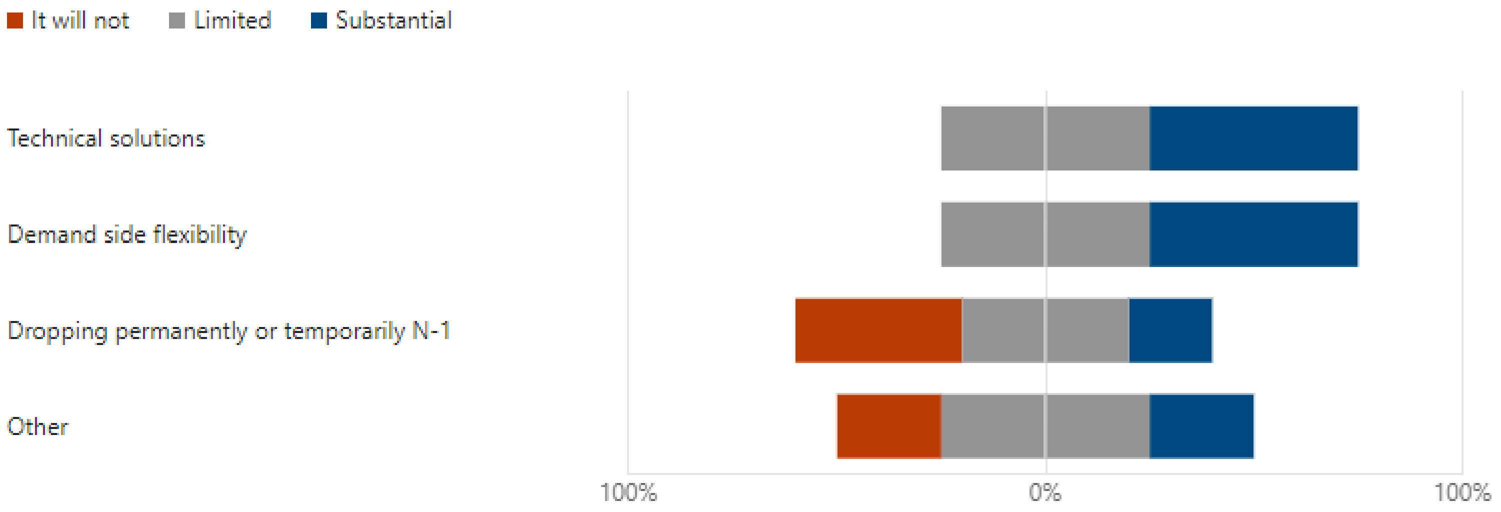
Question 7: If you rank the option 'Other' high in the previous exercise, what other cause are you referring to? [If not, leave blank]

ID ↑	Name	Responses
1	anonymous	Regulation to implement new innovative contracts and tariffs
2	anonymous	Lack of suitable regulatory incentives
3	anonymous	Granting planned outages.
4	anonymous	Lagging regulation, data management/ digitalization
5	anonymous	Inadequate regulatory framework (cap limit to investments and lack of investments incentives).

Question 8: What options to address limited network capacity are in place today? [multiple answers possible]



Question 9: If implemented, to what extent is each category able to address the limited network capacity issue?

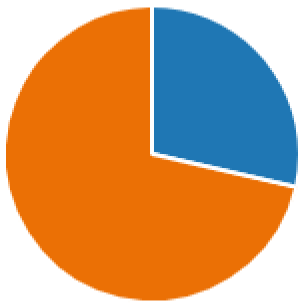


Question 10: Is flexibility a permanent or temporary solution?

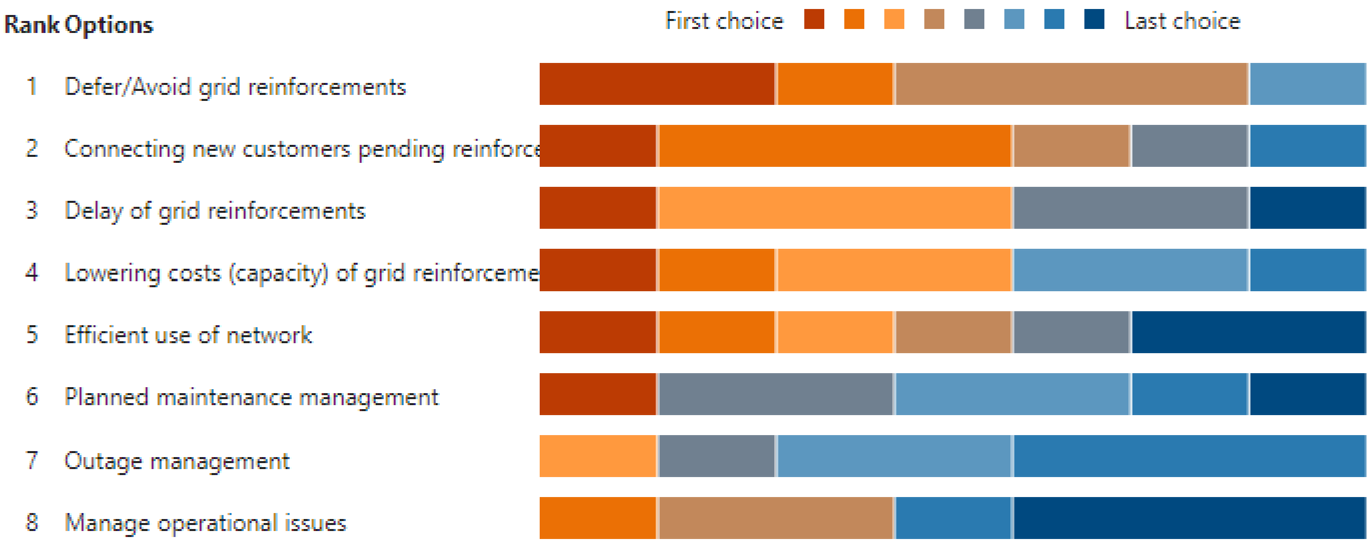
- A temporarily solution only needed during the energy transition
- A permanent solution that will also be deployed after the energy transition has been finished

More Details

Temporary	2
Permanent	5

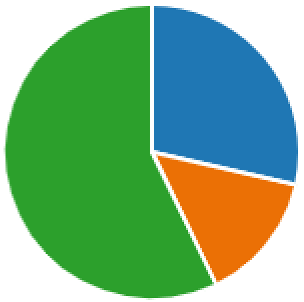


Question 11: If flexibility is considered as part of the solution, what is the main motivation behind implementing flexibility services? [Please rank]



Question 12: Has your DSO quantified the flexibility potential for the different options (listed in the question above)?

yes, it is publicly available	2
yes	1
no	4



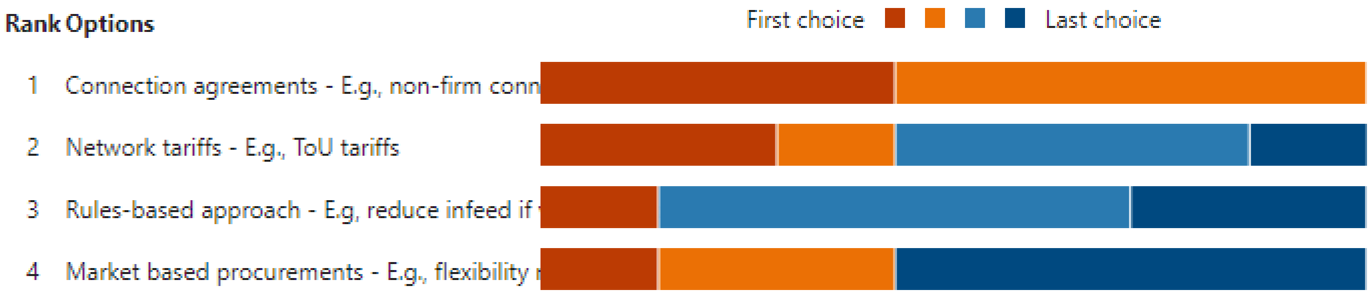
Question 13: If yes, for the different purposes (listed below), what is the flexibility potential in your grid? [In X EUR saved in grid reinforcements, MWs or km of additional network capacity created or other]
If not, do you have plan to calculate this in the near future?

ID ↑	Name	Responses
1	anonymous	As our strategy contains several interlinking innovations that partly challenge the present thinking paradigms, it is difficult to adress potential to the individual aspects above. Flexibility is something we see as an integrated part of a carbon free energy system, it is not something of infrastructure but mainly of energy markets in relation to efficient societal investments in infrastructure
2	anonymous	It will be necessary to calculate in the future.

Question 14: Does your DSO have a DNO-DSO transition plan? Does it have an investment plan? If yes, can you please share?
Please also add any other public documentation links referred to in the questionnaire.

ID ↑	Name	Responses
1	anonymous	We have a strategic theme on this matter with a high level roadmap towards 2030 that starts with coordinated TSO/DSO transport capacity release and change to a near real time capacity release and congestion management where nowadays these are mainly day ahead processes. Towards 2030 we foresee more and more regional security of supply and local balancing acitivites for the DSO as manu sources, flexibility and demand operated in the regional grid and the transport capacity towards the national grid is optimised on the regional balancing potential.
2	anonymous	All our DS are DSO already
3	anonymous	Yes, 2 years in. National Network Local Connections
4	anonymous	Yes. It is not public.

Question 15: Within demand side flexibility, what types of solutions are the main mechanism to deploy flexibility? [Please rank]



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