Research on flexibility in CINELDI
Pilots and TSO/DSO coordination

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Agenda

About FME CINELDI (2016-2024)

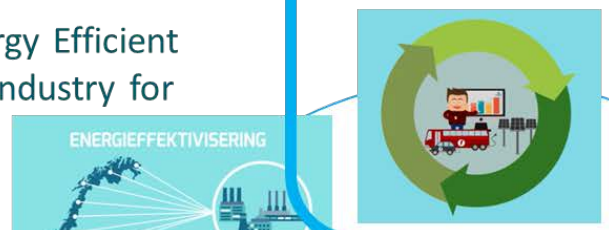
Flexibility as a common priority area (2020-2021)

DSO/TSO Coordination

About FME CINELDI (2016-2024)

CINELDI is one of the Centres for Environment-friendly Energy Research in Norway (FME)

Centre for intelligent electricity distribution – CINELDI



Centre for an Energy Efficient and Competitive Industry for the Future
- HighEFF

Mobility Zero Emission Energy Systems
- MoZEES

Norwegian CCS Research Centre
- NCCS

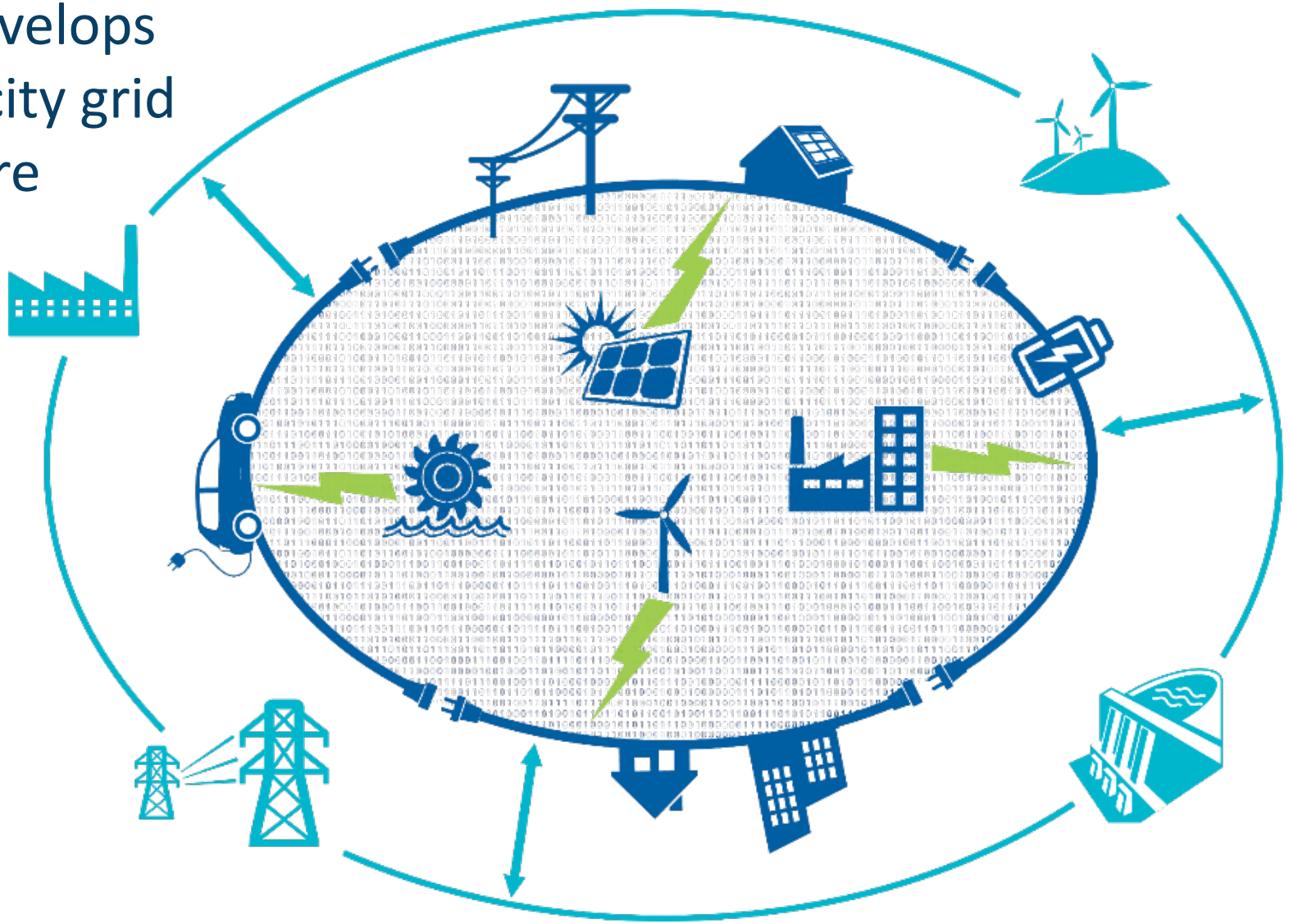
Research Centre for Sustainable Solar Cell Technology
- SUSOLTECH

Norwegian Research Centre for Hydropower Technology
- HydroCen

Norwegian Centre for Sustainable Bio-based Fuels and Energy
- NorSusBio

The Research Centre on Zero Energy Neighbourhoods in Smart Cities **- ZEN**

CINELDI develops
the electricity grid
of the future

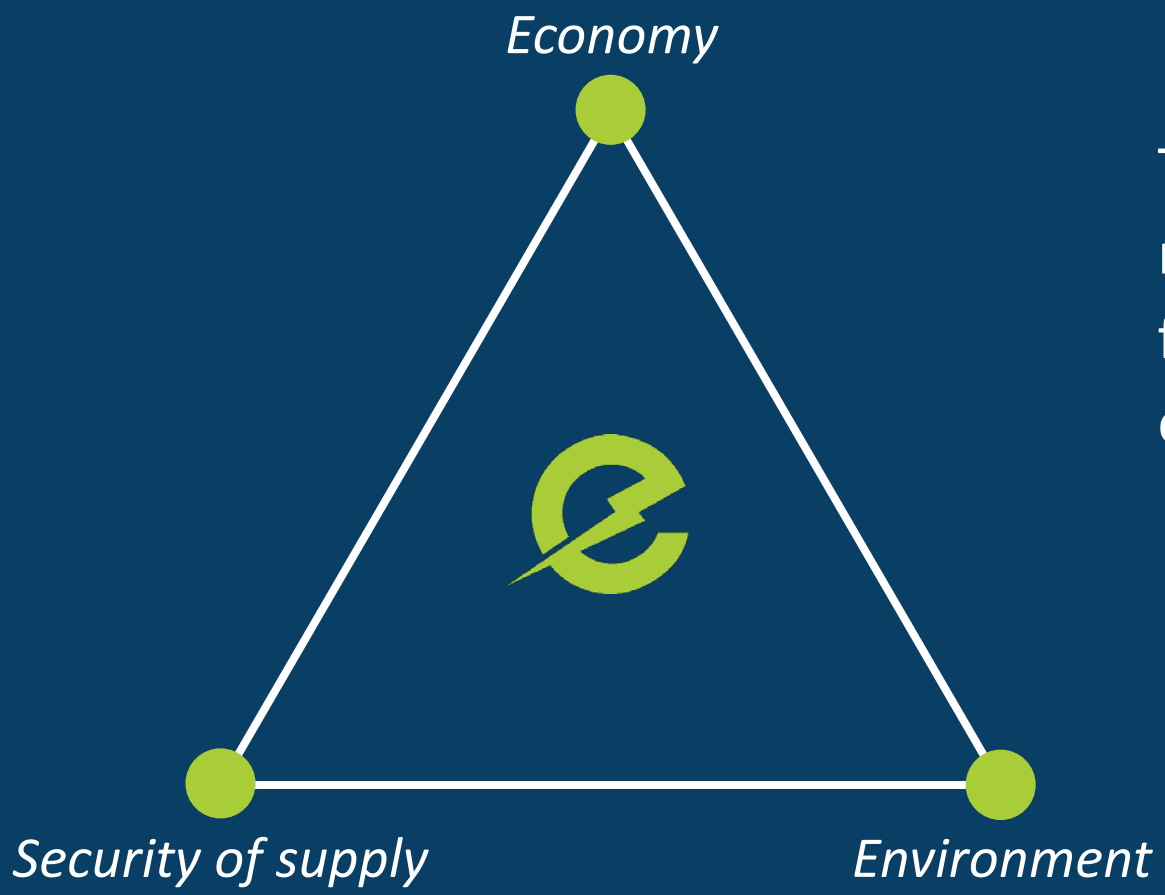


CINELDI

CINELDI Mission

CINELDI works towards digitalising and modernising the electricity distribution grid for higher efficiency, flexibility and resilience.

CINELDI Main goal

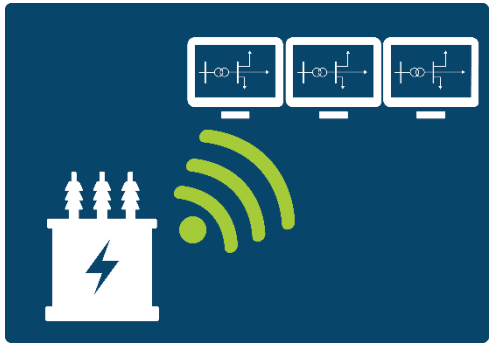


To enable a cost-efficient realisation of the future flexible and robust electricity distribution grid.

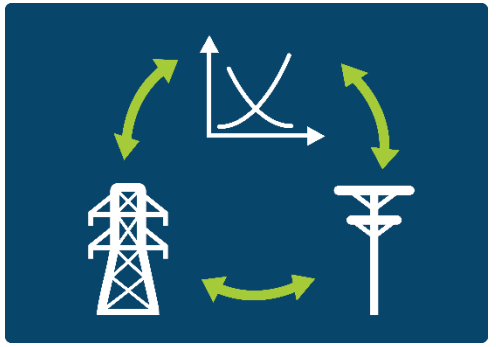
Work Packages

Smart grid development and asset management

Smart grid operation

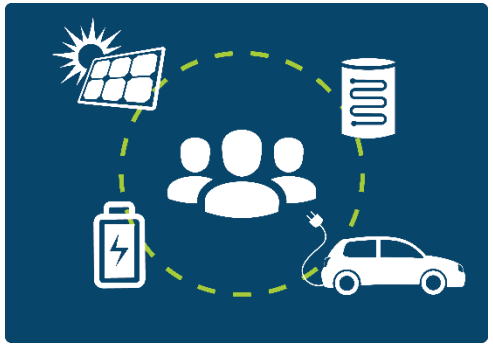


Interaction DSO/TSO



Microgrids

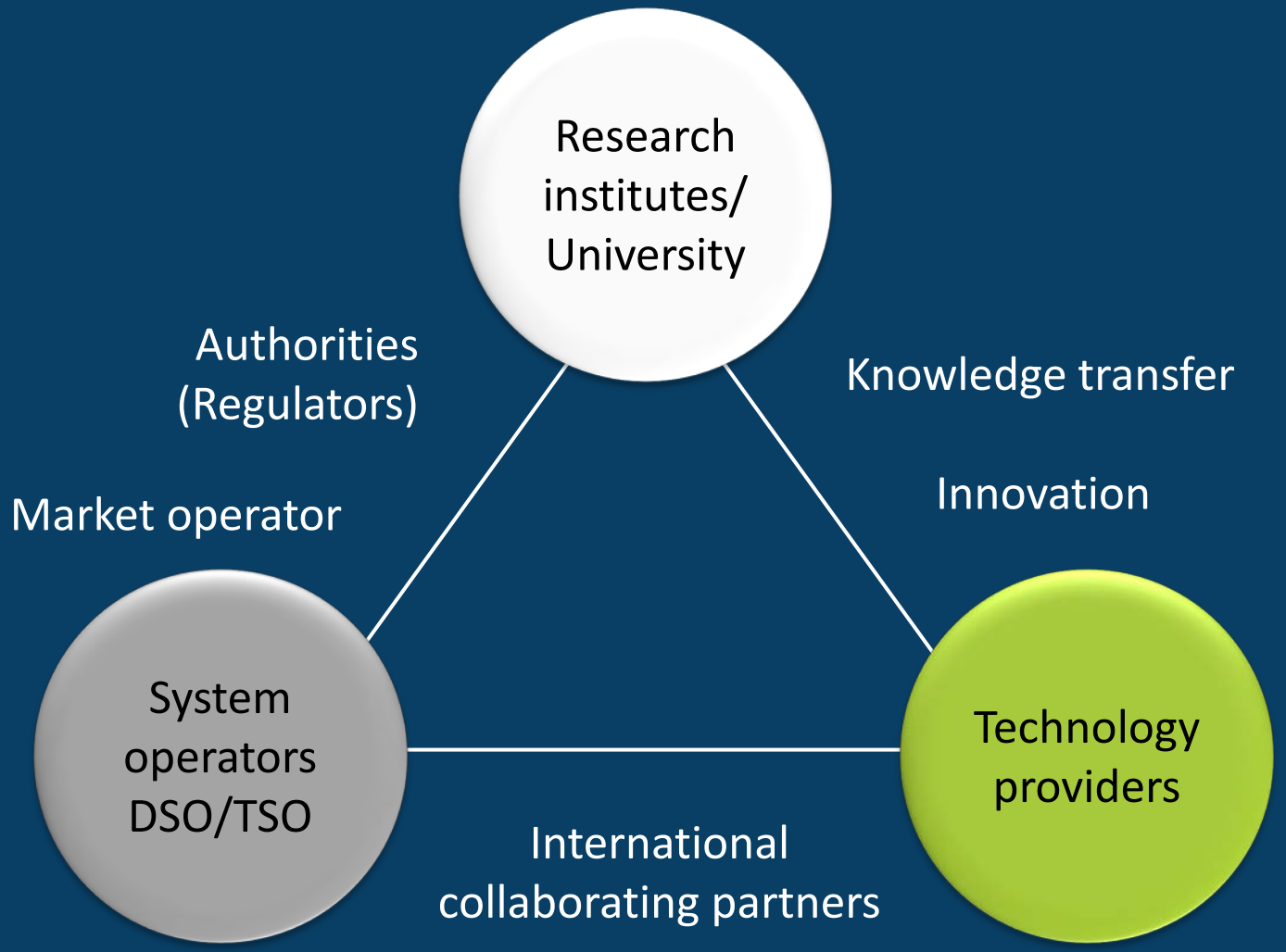
Flexible resources in the power system



Smart grid scenarios and transition strategies

CINELDI in figures

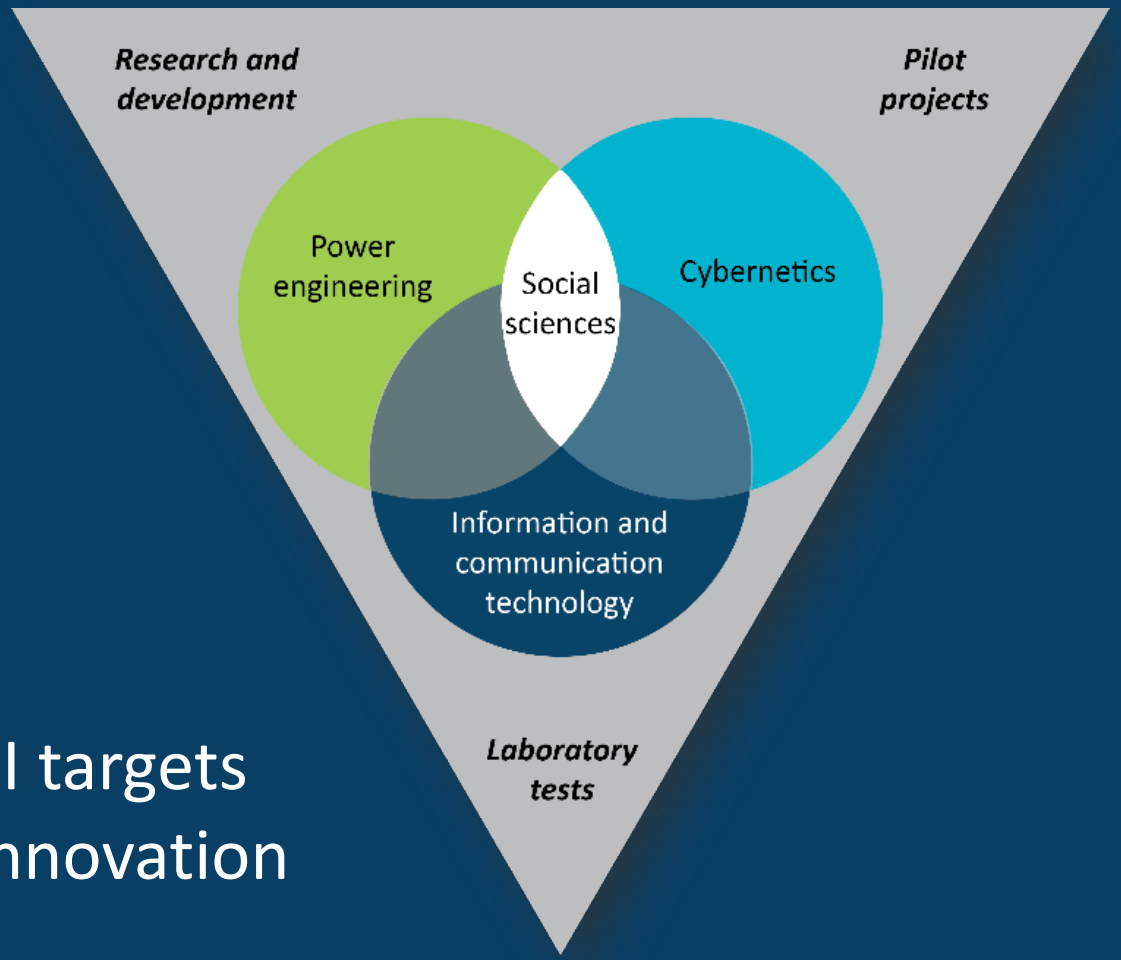
CINELDI partners



National partners

CINELDI

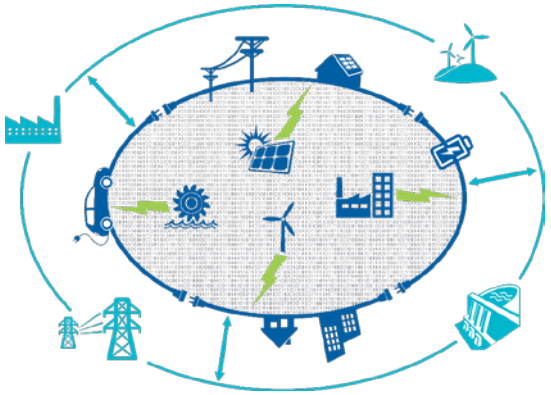
Multidisciplinary research platform



CINELDI targets system innovation

Flexibility as a common priority area (2020-2021)

Why flexibility as a common priority area? (2020-2021)



- Enable a holistic treatment of a topic that affects all research areas in CINELDI
- Gain momentum for advancing the state-of-the-art with regard to utilisation of flexibility in the grid
- Contribute to system innovation in the smart grid transition

Flexibility as a common priority area (2020-2021) (cont.)

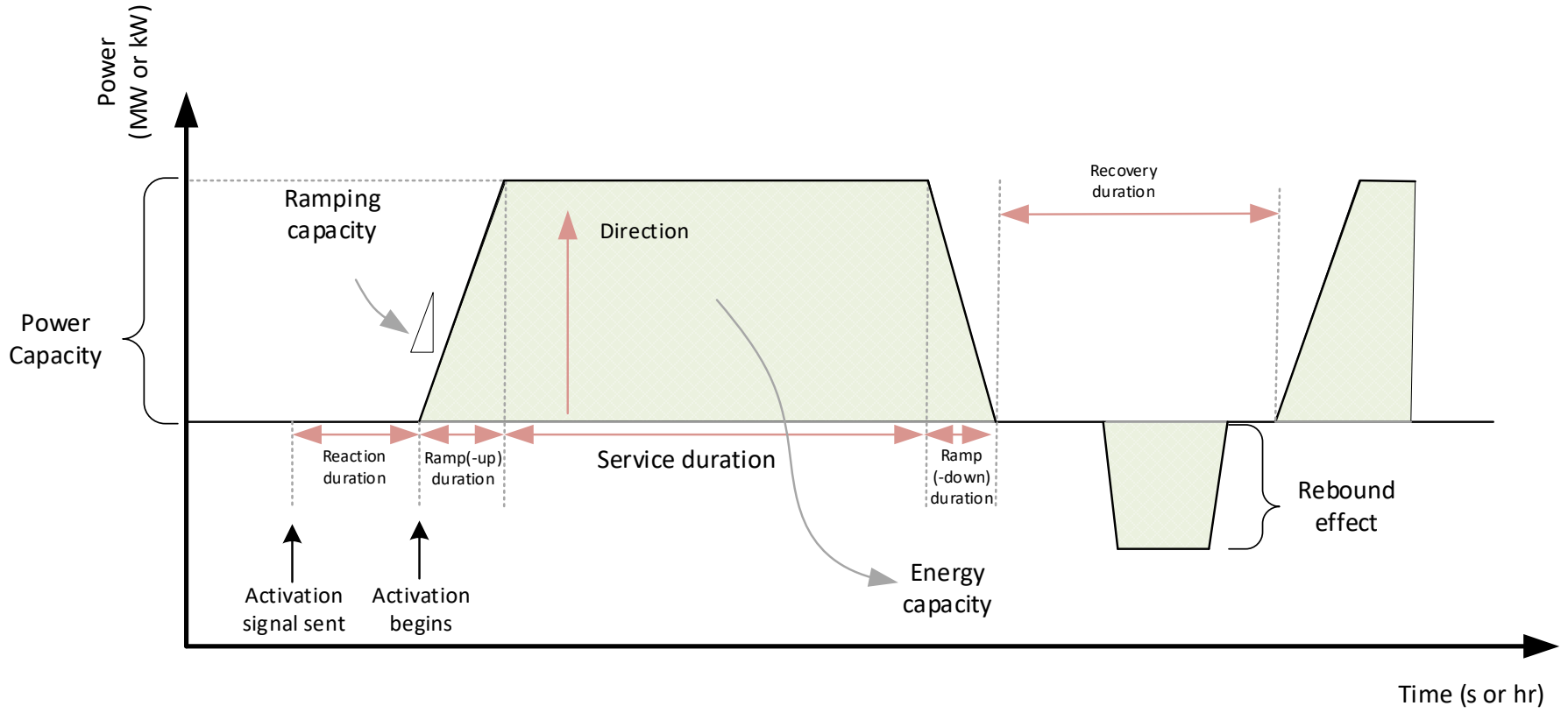
- **Expected electrification** of the energy system, integration of **variable renewables** at end-user level and the rise of **new large-scale industrial loads** will impose new challenges to grid operators (DSO and TSO).
- **Utilization of flexibility** at different grid levels might be an **option to reduce grid investments** compared with the more traditional system reinforcements (new lines, cables, transformers etc.).
- To make this happen, **procurement and activation of flexible resources** need to be incorporated in all phases of the grid management, **from planning to operation**.

Definition of flexibility

- Flexibility is defined as the modification of generation injection and/or consumption patterns, on an individual or aggregated level, often in reaction to an external signal, in order to provide a service within the energy system or maintain stable grid operation [8].

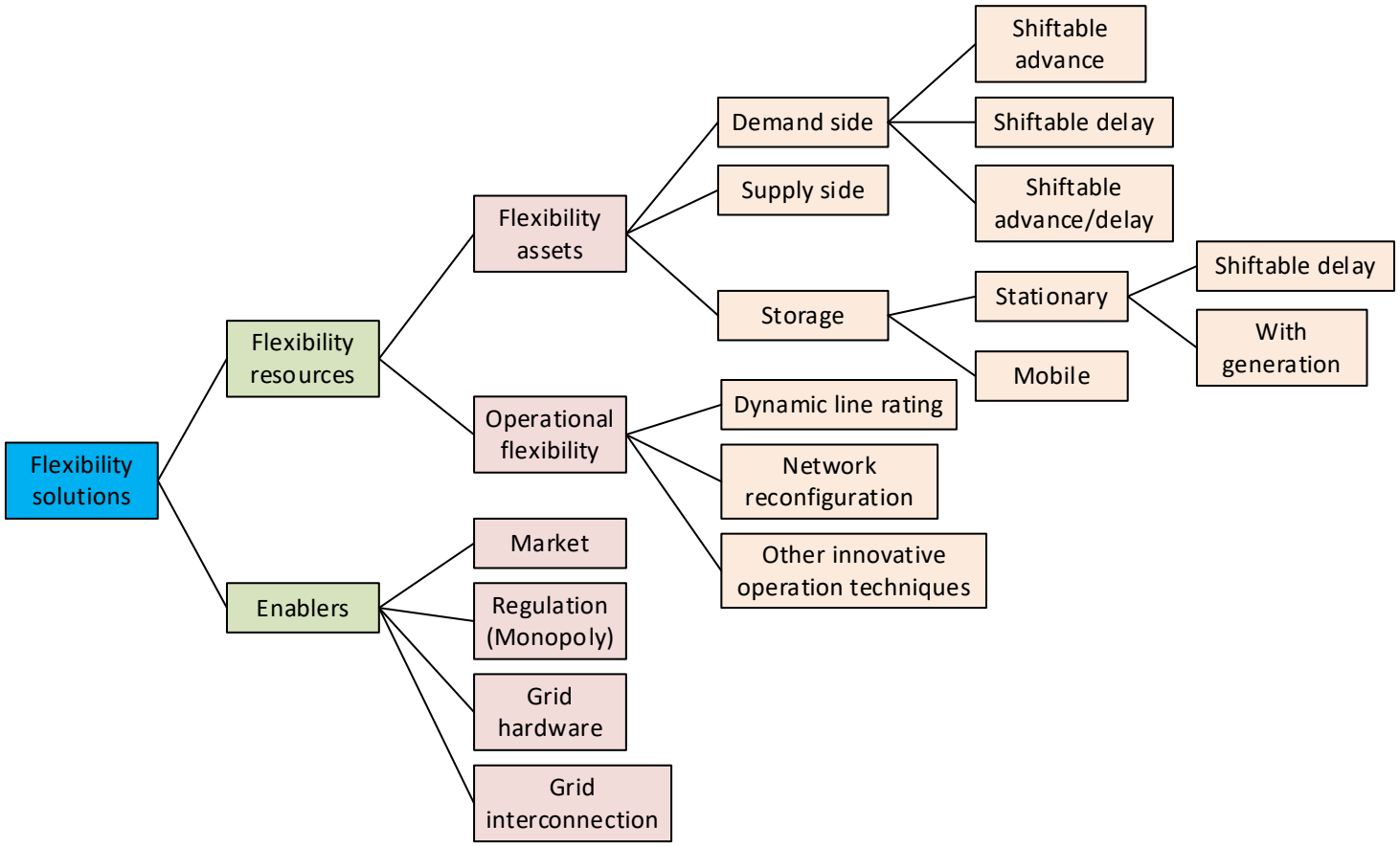
[8] CEDEC, EDSO for Smart Grids, Eurelectric, GEODE, «Flexibility in the energy transition – A Toolbox for Electricity DSOs,» 2018.

Characteristics of flexibility resources



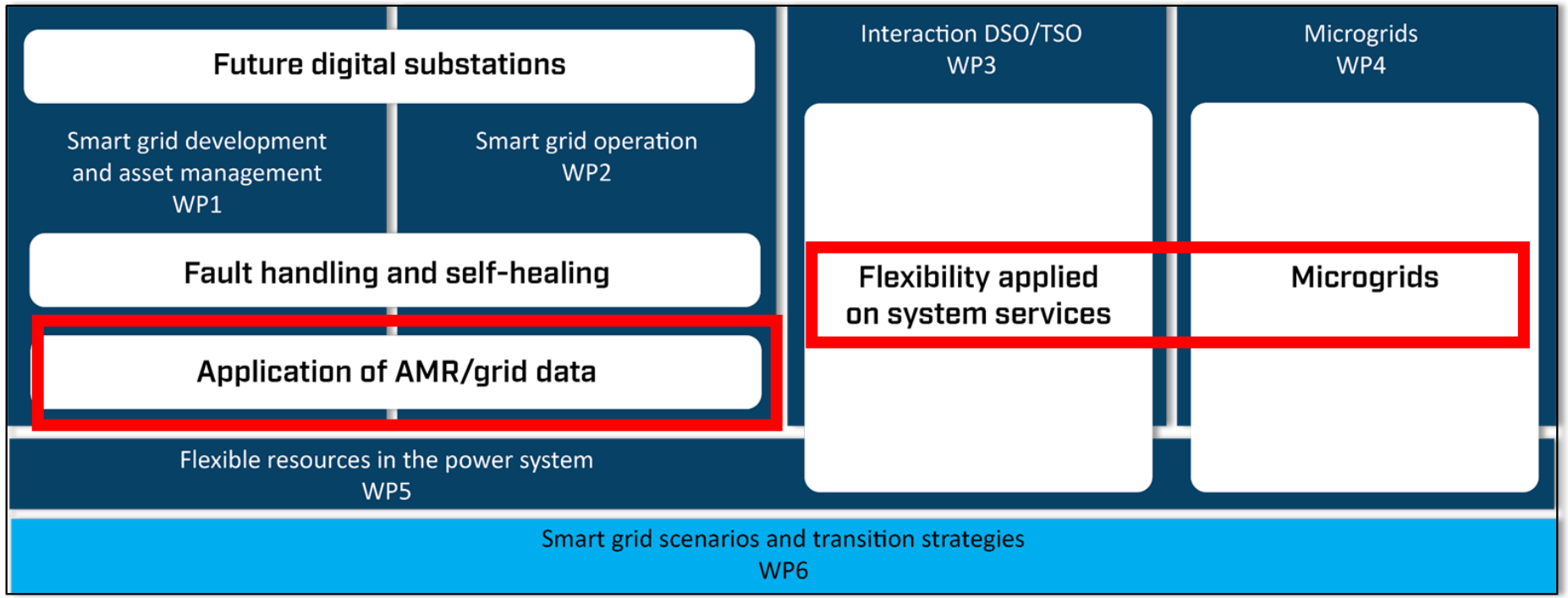
Source: Paper "Comprehensive classifications and characterizations of power system flexibility resources" (Under Per review)

Classification of flexibility resources



Source: Paper "Comprehensive classifications and characterizations of power system flexibility resources" (Under Per review)

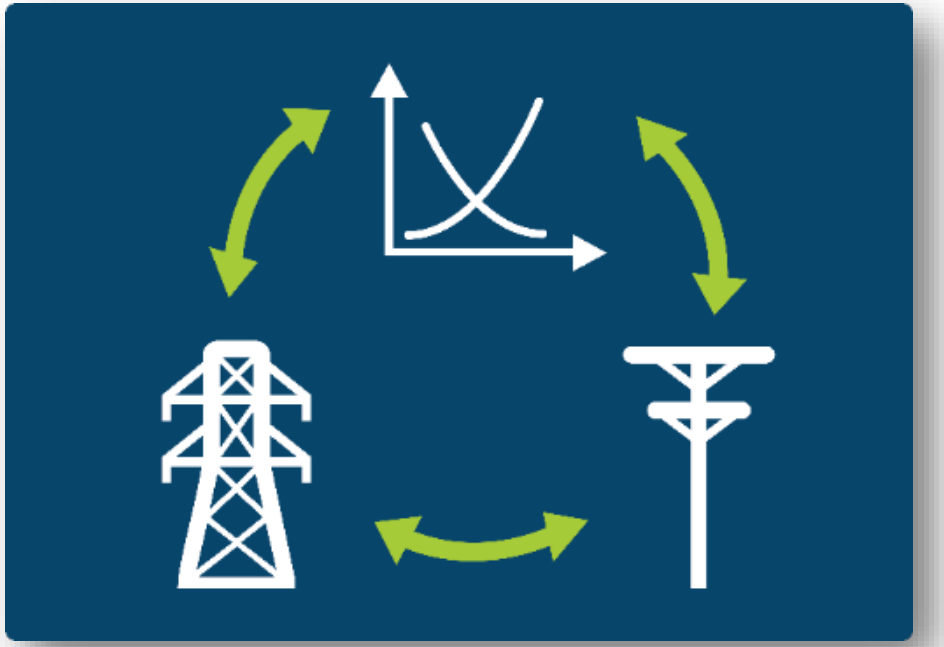
Priority areas for pilot projects in CINELDI



DSO/TSO Coordination

DSO/TSO Coordination in CINELDI is focusing on:

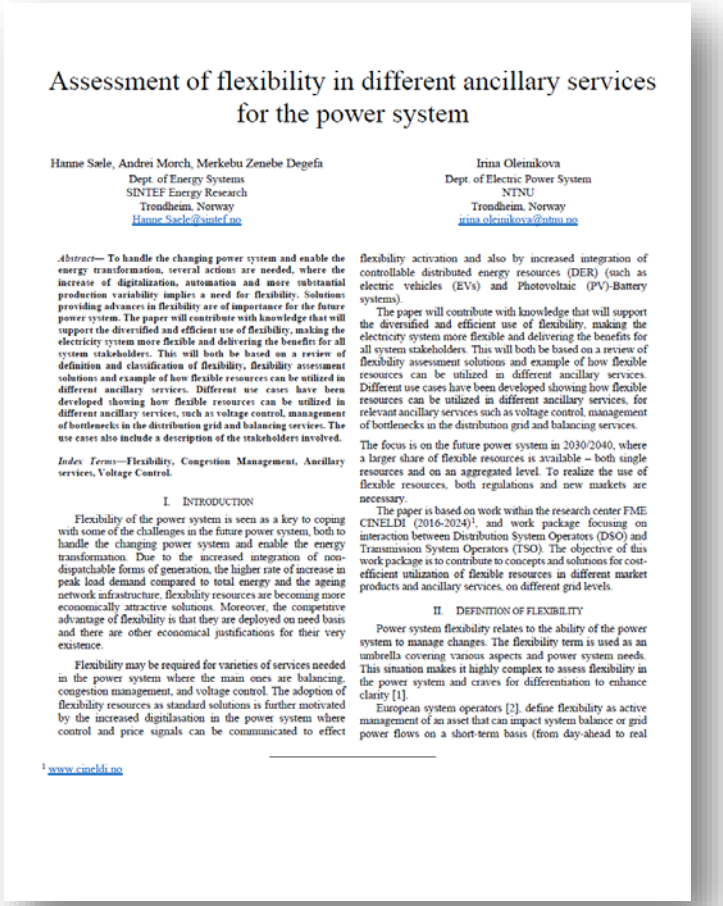
- utilizing flexible resources (DER) in different market products and ancillary services,
- increased observability between the distribution and transmission systems and
- business models regarding utilization of customer flexibility (DER) to all voltage levels.



Use cases for utilization of flexible resources in ancillary services

- Focus on
  - Voltage control
  - Congestion management
  - Balancing

- Work presented in paper at EEM 2020



Assessment of flexibility in different ancillary services for the power system

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Abstract— To handle the changing power system and enable the energy transformation, several actions are needed, where the increase of digitalization, automation and more substantial production variability implies a need for flexibility. Solutions providing advances in flexibility are of importance for the future power system. The paper will contribute with knowledge that will support the diversified and efficient use of flexibility, making the electricity system more flexible and delivering the benefits for all system stakeholders. This will both be based on a review of definition and classification of flexibility, flexibility assessment solutions and example of how flexible resources can be utilized in different ancillary services. Different use cases have been developed showing how flexible resources can be utilized in different ancillary services, such as voltage control, management of bottlenecks in the distribution grid and balancing services. The use cases also include a description of the stakeholders involved.

Index Terms—Flexibility, Congestion Management, Ancillary services, Voltage Control.

I. Introduction

Flexibility of the power system is seen as a key to coping with some of the challenges in the future power system, both to handle the changing power system and enable the energy transformation. Due to the increased integration of non-dispatchable forms of generation, the higher rate of increase in peak load demand compared to total energy and the ageing network infrastructure, flexibility resources are becoming more economically attractive solutions. Moreover, the competitive advantage of flexibility is that they are deployed on need basis and there are other economical justifications for their very existence.

Flexibility may be required for varieties of services needed in the power system where the main ones are balancing, congestion management, and voltage control. The adoption of flexibility resources as standard solutions is further motivated by the increased digitilasation in the power system where control and price signals can be communicated to effect flexibility activation and also by increased integration of controllable distributed energy resources (DER) (such as electric vehicles (EVs) and Photovoltaic (PV)-Battery systems).

The paper will contribute with knowledge that will support the diversified and efficient use of flexibility, making the electricity system more flexible and delivering the benefits for all system stakeholders. This will both be based on a review of flexibility assessment solutions and example of how flexible resources can be utilized in different ancillary services. Different use cases have been developed showing how flexible resources can be utilized in different ancillary services, for relevant ancillary services such as voltage control, management of bottlenecks in the distribution grid and balancing services.

The focus is on the future power system in 2030/2040, where a larger share of flexible resources is available – both single resources and on an aggregated level. To realize the use of flexible resources, both regulations and new markets are necessary.

The paper is based on work within the research center FME CINELDI (2016-2024)[1], and work package focusing on interaction between Distribution System Operators (DSO) and Transmission System Operators (TSO). The objective of this work package is to contribute to concepts and solutions for cost-efficient utilization of flexible resources in different market products and ancillary services, on different grid levels.

II. Definition of Flexibility

Power system flexibility relates to the ability of the power system to manage changes. The flexibility term is used as an umbrella covering various aspects and power system needs. This situation makes it highly complex to assess flexibility in the power system and craves for differentiation to enhance clarity [1].

European system operators [2], define flexibility as active management of an asset that can impact system balance or grid power flows on a short-term basis (from day-ahead to real

[1] www.cineldi.no

https://www.researchgate.net/publication/344689881_Assessment_of_flexibility_in_different_ancillary_services_for_the_power_system

Market architectures for TSO-DSO interaction

- Five different architectures or coordination schemes (CSs) were proposed in H2020 SmartNet-project

- Each CS presents a different way of organizing the coordination between transmission and distribution system operators (TSOs and DSOs) for dealing with congestion management and balancing.

Market architectures for TSO-DSO interaction

Coordination scheme	Description
A. Centralized AS market model	**One common market** for ancillary services, operated by the TSO, for both resources connected at transmission and distribution level. There is no separate local market.
B. Local AS market model	The **DSO organizes a local market** for resources connected to the DSO-grid and, after solving local grid constraints, **aggregates and offers the remaining bids to the TSO**.
C. Shared balancing responsibility model	Balancing responsibilities are exercised separately by TSO and DSO, each on its own network. The **DSO organizes a local market** while respecting an **exchange power schedule agreed with the TSO**, while the TSO has no access to the resources connected to the distribution grid.
D. Common TSO-DSO AS market model	The **TSO and the DSO have a common objective** to decrease the cost of the resources they need. This common objective could be realized by the **joint operation of a common market** (centralized variant), or the dynamic integration of a local market, operated by the DSO, and a central market, operated by the TSO (decentralized variant).
E. Integrated flexibility market model	The market is open for both regulated (TSOs, DSOs) and non-regulated market parties (BRPs, CMPs), which requires the introduction of an **independent market operator** to guarantee neutrality. As a consequence, the boundaries between intraday markets and ancillary services could fade away.

Use case:
Balancing services

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The need for balancing services

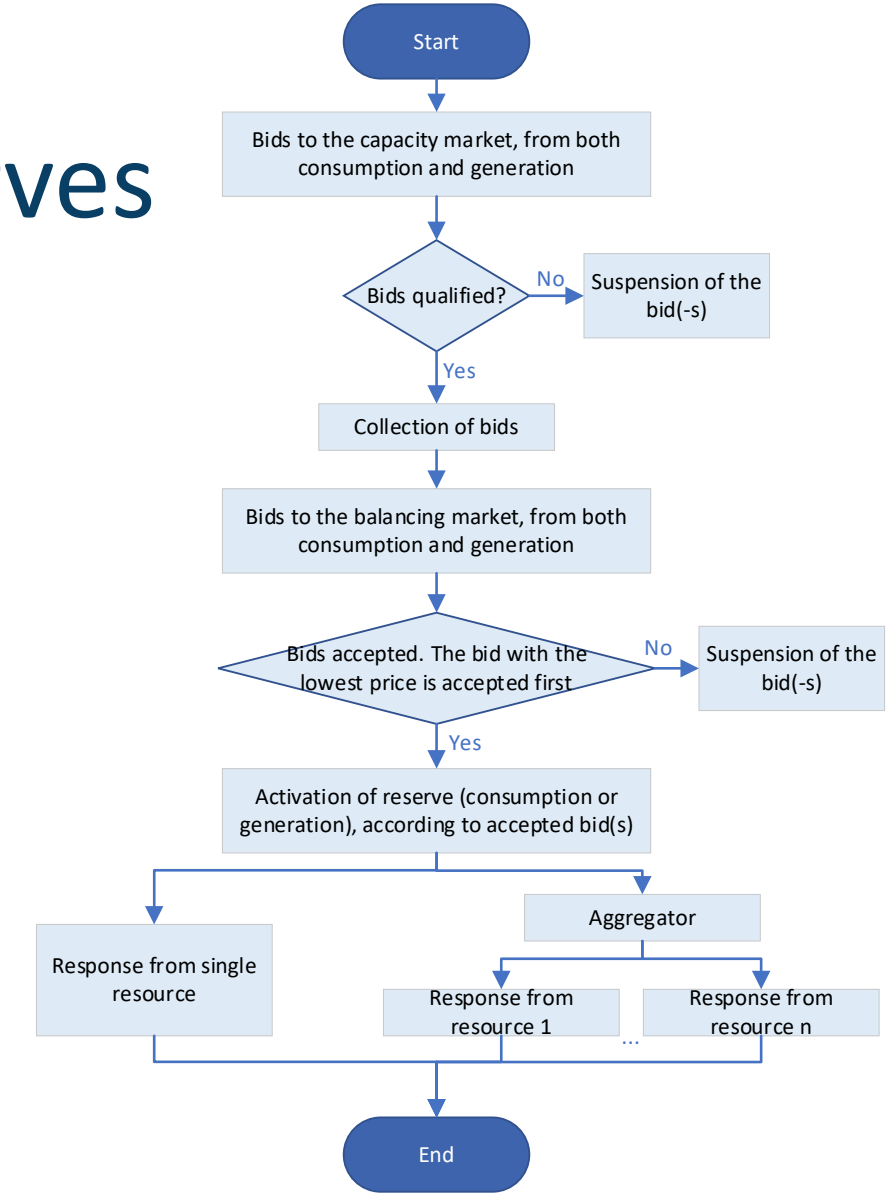
- To maintain the stability of the power system the instantaneous generation and consumption have to be in balance at all times
- The increasing amount of non-dispatchable forms of generation in the power system makes it more challenging to balance the system

Description of balancing services

Balancing service	Description
Fast Frequency Reserves (FFR)	• Activated within 1 second, when the system frequency falls below a certain level (49.5 Hz or 49.7 Hz). • In a pilot project in 2018 the Norwegian TSO demonstrated how industry, data centres and EVs (aggregated) could contribute with FFR.
Primary Reserves (Frequency Containment Reserves - FCR)	• Often rotating reserves in the power generators. • Activated automatically when the frequency is lower than 49.9 Hz or higher than 50.1 Hz.
Secondary Reserves (Automatic Frequency Restoration Reserves - aFRR)	• Activated to release primary reserves (so they are available to handle new errors and unbalances). The response should be within 2 min. • In Norway today, mainly generation are offering this service, but it is planned to also include flexible loads.
Tertiary reserves (Manual Frequency Restoration Reserves - mFRR)	• Activated if there are further need for frequency regulation, or when handling regional bottlenecks and imbalances in the grid. • These are manual reserves that activates within 15 minutes

Use case for tertiary reserves

1. Capacity (option) market for balancing reserves
   - established to secure liquidity of reserves (both generation and consumption) for tertiary regulation. The duration of the options is on season (typically October – April) and week.
2. Daily bids to the balancing market.
   - Bids are activated according to their price -> the bid with the lowest price is activated first.
3. Corresponding reserve should respond within 15 minutes
   - activation directly towards a single resource or as aggregated flexibility from several smaller resources.
4. Dependent on the grid level where the balancing market is implemented, the buyer of flexibility services could be the TSO or DSO.



Use case:
Congestion management

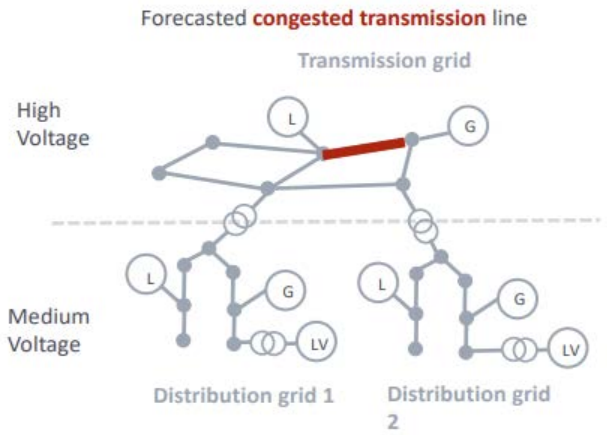
Congestion Management

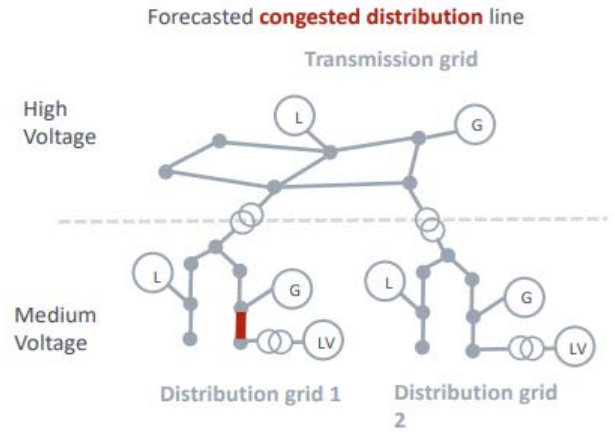
Physical congestion:

Any network situation, where forecasted or realised power flows violate the thermal limits of the elements of the grid and voltage stability or the angle stability limits of the power system (NC for Capacity Allocation and Congestion Management)

There are several ways for a DSO to approach congestion management:

- Traditional way, by utilising own flexible assets as for example on-load tap changer (OLTC) transformers or changes of the topology
- Use of external flexibility, not being owned by the operator





Source: H2020 SmartNet http://smartnet-project.eu/

Phases in Congestion Management

A. **Product pre-qualification**, which verifies whether the given unit can technically deliver its product. **Grid (system) pre-qualification** verifies, whether the given unit can realise the product delivery, considering characteristics of the grid.

B. **Forecasting phase**, where the grid utilisation is planned, and the potential congestions identified.

C. **Market phase**, which includes collection of the bids and evaluation of the contracts.

D. **Monitoring and activation phase**. Activation of bids for congestion management and cooperation among system operators in real time.

E. **Measurement and settlement phase**: validation of the delivery.

(Source: ENTSO-E, "An integrated approach to active system management")

Alternatives for the Market phase

- Centralised Ancillary Services market model
- Local Ancillary services market
- Shared balancing responsibilities model
- Common TSO-DSO Ancillary services market model
- Integrated flexibility market model

(Source: H2020 SmartNet)

Pilot projects – Flexibility market

Objective

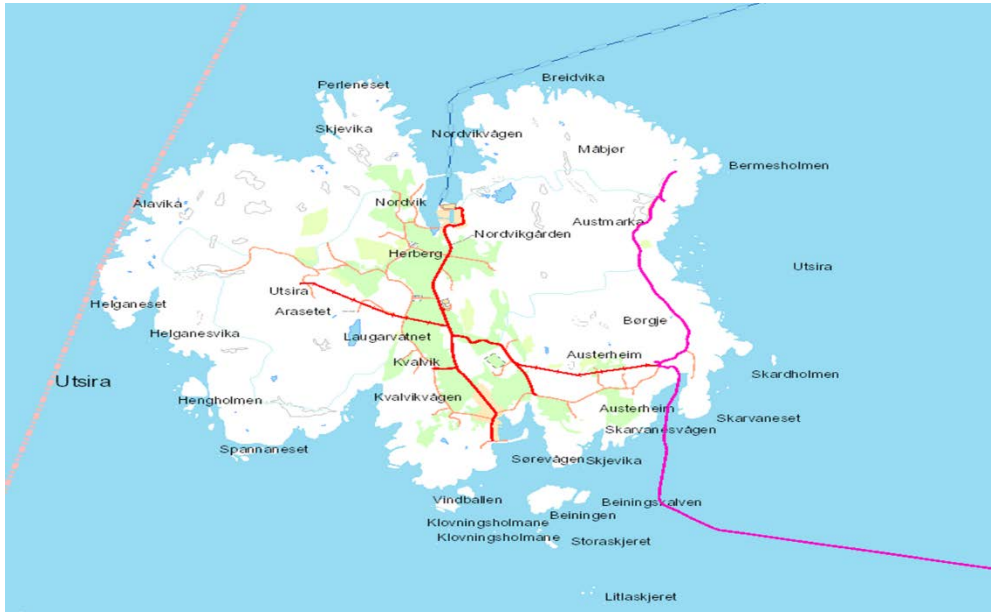
- Demonstrate how/if a market-based solution can be used for congestion management in the distribution grid

Locations

- Utsira Smart Island (DSO: Haugaland Kraft Nett)
- Bremangerlandet (DSO: SFE Nett)

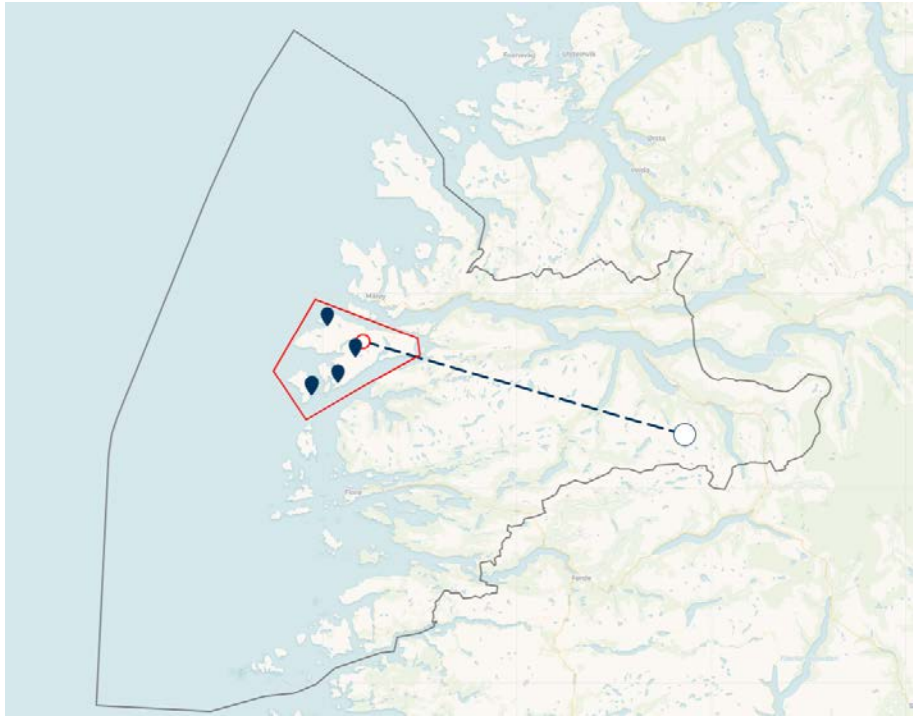
Utsira Smart Island – Haugaland Kraft Nett

- Island connected to the main land via a submarine cable
- Electric ferry
- Flexible resources
  - PV, wind, electric battery
- Energy Management System
  - Orchestration of flexible resources
  - Optimize power flow
- Monitoring available flexibility (Dashboard under development)
- Nodes platform will be used to establish a flexibility market



Bremangerlandet – SFE Nett

- Grid problems today (problems with voltage quality in periods of the year)
- Industrial customers can contribute with flexibility
- A new power line is planned to be finalised in 2022.
- A pilot for flexibility market is planned -> a temporary solution while waiting for the new power line
- Status:
  - Smart meter data is analysed to map flexible resources
  - Nodes platform will be established winter 2020/2021



Summary

- CINELDI works towards digitalising and modernising the electricity distribution grid for higher efficiency, flexibility and resilience, also including how flexible resources (DER) can be utilized in different market products and ancillary services.
- To utilize benefits for DSO and TSO offered by flexibility resources, new use cases will be developed and elaborated, focusing also on possible actors, required market and regulatory arrangements, and business models.
- Pilot projects will demonstrate marked based activation of flexible resources – as an alternative to traditional grid investments

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Centre for intelligent electricity distribution
- to empower the future Smart Grid

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