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- to empower the future Smart Grid

Classifying and characterizing power system flexibility solutions

DigiSect 2024 workshop, 2024-05-17

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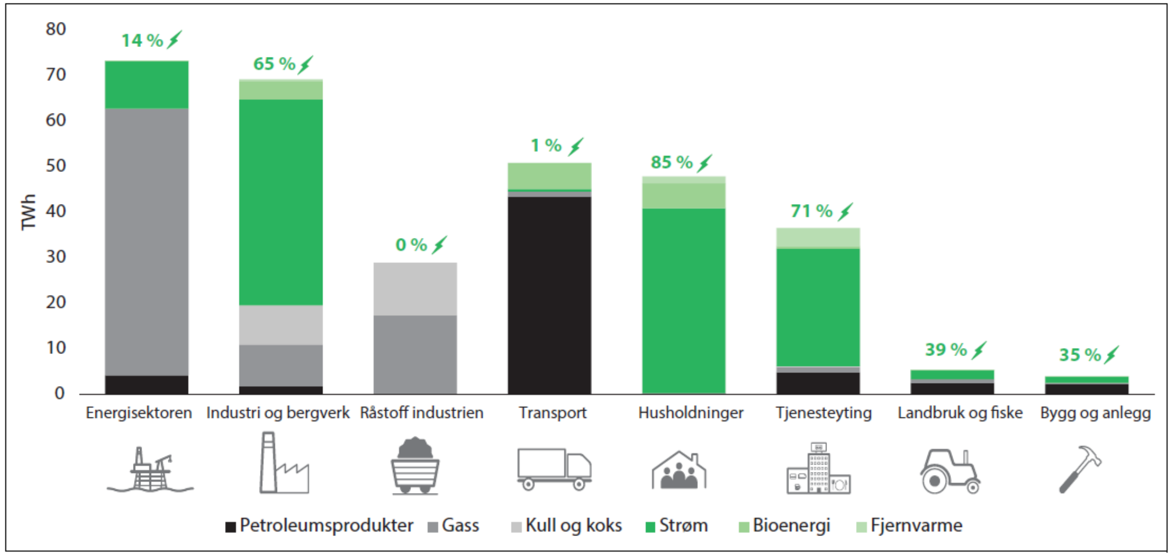
Norwegian perspective on flexibility and sector-coupling



Figur 3.5 Norsk energibruk i 2019.

Kilde: SSB (2020).

Source: OED, 'Energi til arbeid – langsiktig verdiskaping fra norske energiressurser' [Report to the Norwegian Parliament on Energy Policy], Oslo, Meld. St. 25 (2020–2021). [Online]. Available: https://www.regjeringen.no/no/dokumenter/meld.-st.-36-20202021/id2860081/

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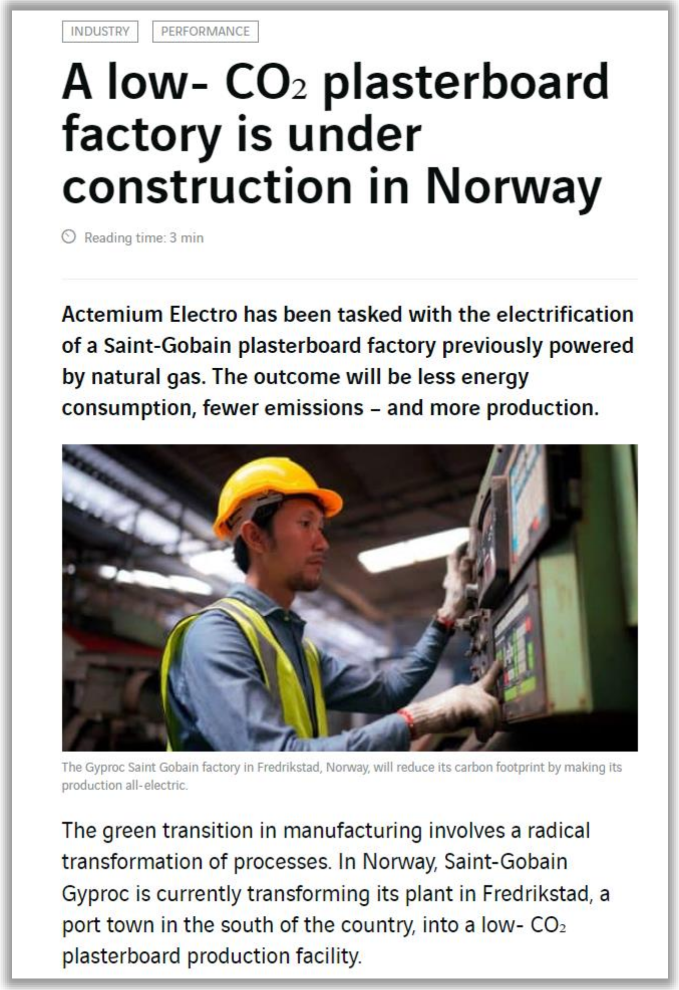
Electrification of Norwegian industry



INDUSTRY PERFORMANCE

A low- CO_2 plasterboard factory is under construction in Norway

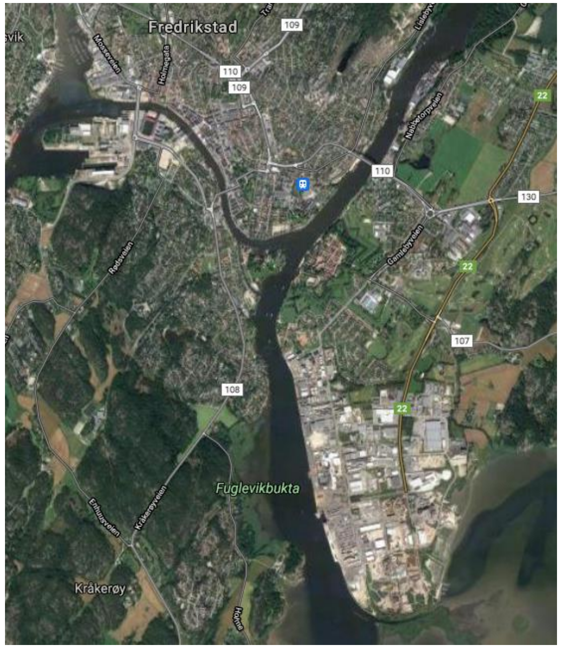
Reading time: 3 min

Actemium Electro has been tasked with the electrification of a Saint-Gobain plasterboard factory previously powered by natural gas. The outcome will be less energy consumption, fewer emissions – and more production.

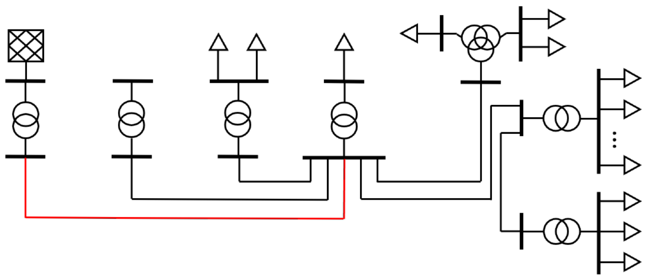
The Gyproc Saint Gobain factory in Fredrikstad, Norway, will reduce its carbon footprint by making its production all-electric.

The green transition in manufacturing involves a radical transformation of processes. In Norway, Saint-Gobain Gyproc is currently transforming its plant in Fredrikstad, a port town in the south of the country, into a low- CO_2 plasterboard production facility.

Source: https://www.theagilityeffect.com/en/article/a-low-co%E2%82%82-plasterboard-factory-is-under-construction-in-norway/



Source: S. Sandell, D. Bjerkehagen, I. B. Sperstad. "Load analysis for evaluating flexibility needs in the planning of an industrial distribution grid", in *SEST2022*, Eindhoven, 2022, DOI: [10.1109/SEST53650.2022.9898467](https://doi.org/10.1109/SEST53650.2022.9898467).



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Outline of presentation

Power system flexibility…

- What?
- How?
- Why?
- Why *not*?

- …and *why* yet another review and classification of power system flexibility?

Why yet another review and classification of power system flexibility?

Flexibility can be classified according to…

- resources'/assets' place and role in the electricity supply chain
- the technologies or type of end-user or grid user involved
- if load can be delayed, postponed and/or curtailed
- its availability
- activation and control mechanism
- which actor is activating flexibility
- the motivation for offering flexibility
- the need for flexibility

What is flexibility?

Source	Definition
CIGRE WG, 1995 [25]	“the ability to adapt the planned development of the power system, quickly and at reasonable cost, to any change, foreseen or not, in the conditions which prevailed at the time it was planned.”
IEA, 2011 [26]	“the extent to which a power system can modify electricity production or consumption in response to variability, expected or otherwise. In other words, it expresses the capability of a power system to maintain reliable supply in the face of rapid and large imbalances, whatever the cause.”
H. Holttinen et al., 2013 [27]	“ability to accommodate the variability and uncertainty in the load-generation balance while maintaining satisfactory levels of performance for any time scale.”
Heussen et al., 2013 [28]	"the capability of altering their generation/consumption pattern with limited impact on their primary energy service"
Eurelectric, 2014 [29]	“the modification of generation injection and/or consumption patterns in reaction to an external signal (price signal or activation) in order to provide a service within the energy system.”
B. Drysdale et al., 2015 [30]	"The degree of flexibility, i.e. the ability of a load to vary in response to an external signal with minimal disruption to consumer utility, varies between load categories."
Ulbig & Anderson, 2017 [1]	“Operational flexibility is the technical ability of a power system unit to modulate electrical power feed-in to the grid and/or power outfeed from the grid over time.”
EPRI, 2016 [31]	“the ability to adapt to dynamic and changing conditions, for example, balancing supply and demand by the hour or minute, or deploying new generation and transmission resources over a period of years.”
Zhao et al., 2016 [16]	"Flexibility at a given state is the ability of a system to respond to a range of uncertain future states by taking an alternative course of action within acceptable cost threshold and time window. Flexibility is an inherent property of a system."
ENTSO-E, 2017 [32]	“the active management of an asset that can impact system balance or grid power flows on a short-term basis, i.e. from day-ahead to real-time.”
Hsieh & Anderson, 2017 [33]	"Flexibility is the capability of the power system to maintain balance between generation and load under uncertainty."
CEDEC, 2018 [34]	"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."
CEER, 2018 [35]	“the capacity of the electricity system to respond to changes that may affect the balance of supply and demand at all times.”
IEA, 2018 [10]	“all relevant characteristics of a power system that facilitates the reliable and cost-effective management of variability and uncertainty in both supply and demand.”
IRENA, 2018 [4]	“the capability of a power system to cope with the variability and uncertainty that VRE (variable renewable energy) generation introduces into the system in different time scales, from the very short to the long term, avoiding curtailment of VRE and reliably supplying all the demanded energy to customers"
IEA, 2019 [5]	"the ability of a power system to reliably and cost-effectively manage the variability and uncertainty of demand and supply across all relevant timescales, from ensuring instantaneous stability of the power system to supporting long-term security of supply"
ISGAN, 2019 [3]	"Power system flexibility relates to the ability of the power system to manage changes."

Based on: M. Z. Degefa, I. B. Sperstad, and H. Sæle, "Comprehensive classifications and characterizations of power system flexibility resources", *Electric Power Systems Research*, vol. 194, p. 107022, 2021. Available: https://doi.org/10.1016/j.epsr.2021.107022.

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What is flexibility?

- Flexibility is the *capability and willingness* to modify production and/or consumption pattern, on an individual or aggregated level, often as a response to an external signal, to offer a service to the power system or contribute to stable grid operation.

G. Kjølle, K. Sand, and E. Gramme, 'Scenarios for the future electricity distribution grid', in *CIRED 2021 Conference*, Geneva / virtual, 2021, Paper 0858.

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What is flexibility?

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- *Explicit flexibility* – the resource can respond to external control signals, enabled by ICT

- *Implicit flexibility* – the flexibility resource is primarily controlled indirectly through price signals

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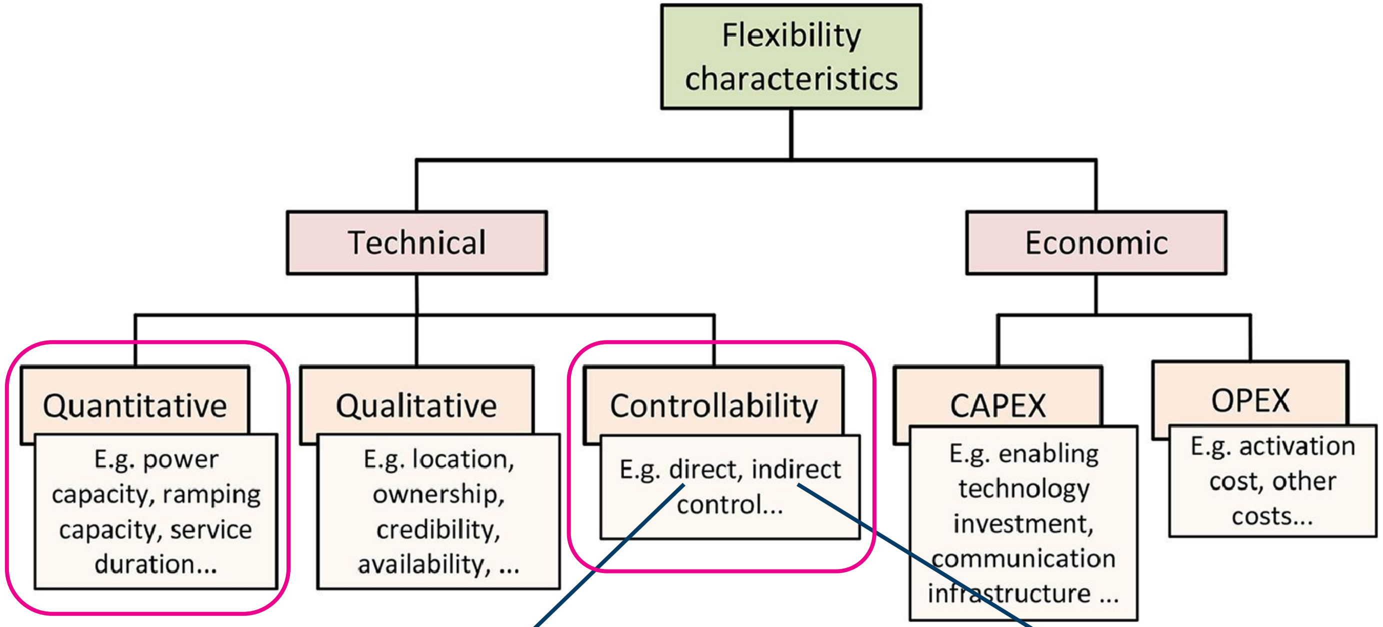
Characteristizing power system flexibility



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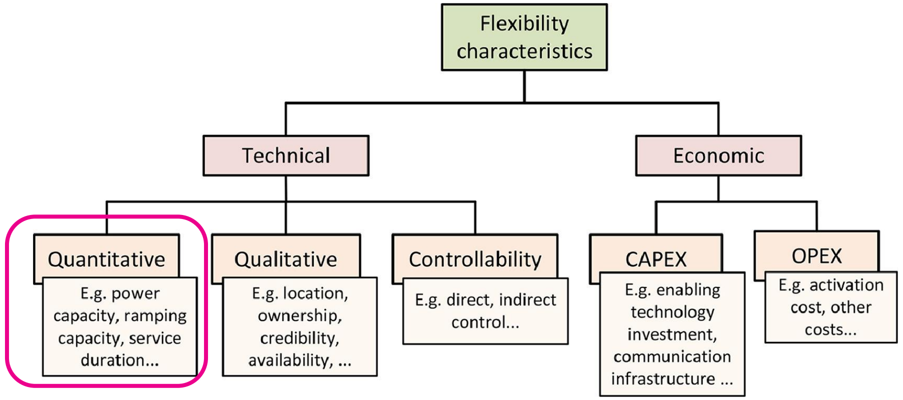
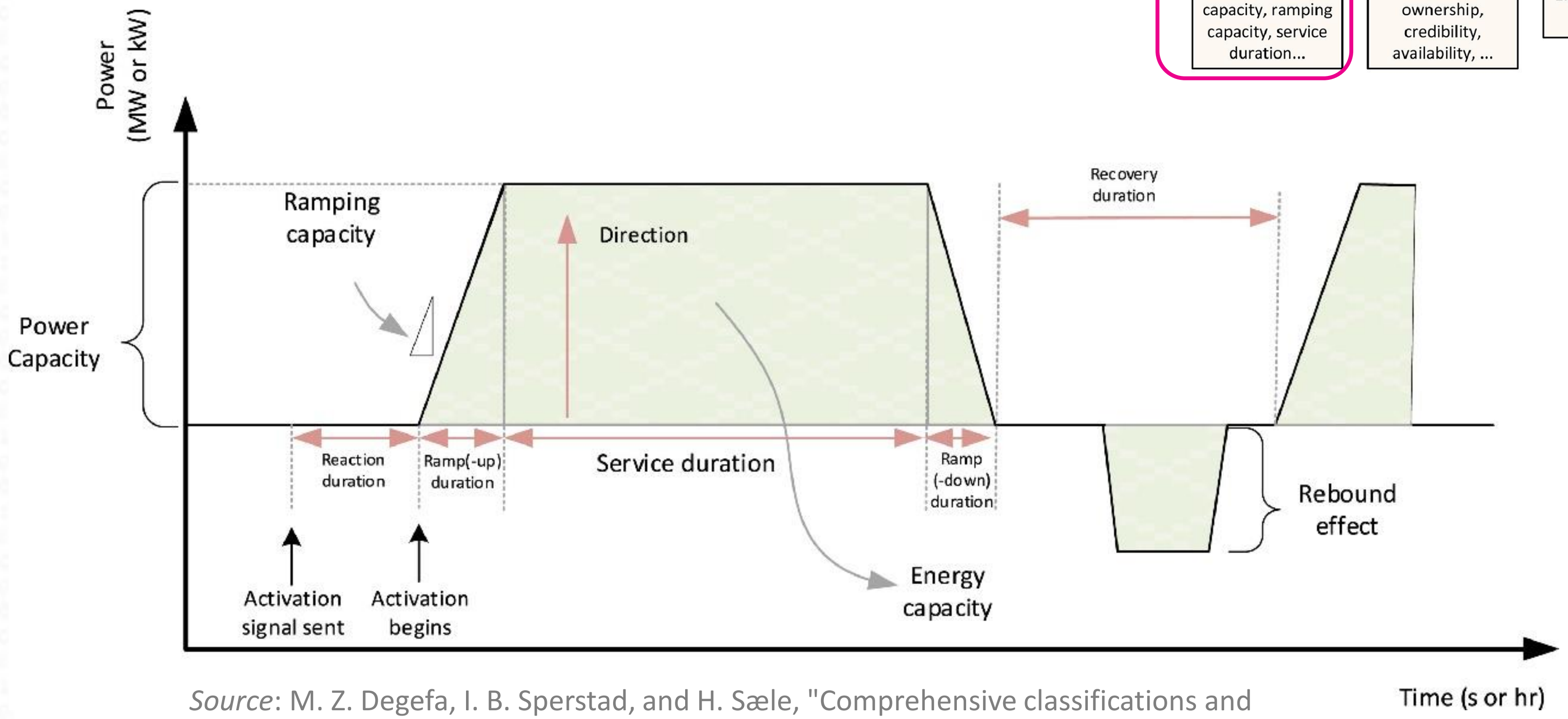
Characterizing power system flexibility





Source: M. Z. Degefa, I. B. Sperstad, and H. Sæle, "Comprehensive classifications and characterizations of power system flexibility resources", *Electric Power Systems Research*, vol. 194, p. 107022, 2021. Available: https://doi.org/10.1016/j.epsr.2021.107022.

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Classifying power system flexibility

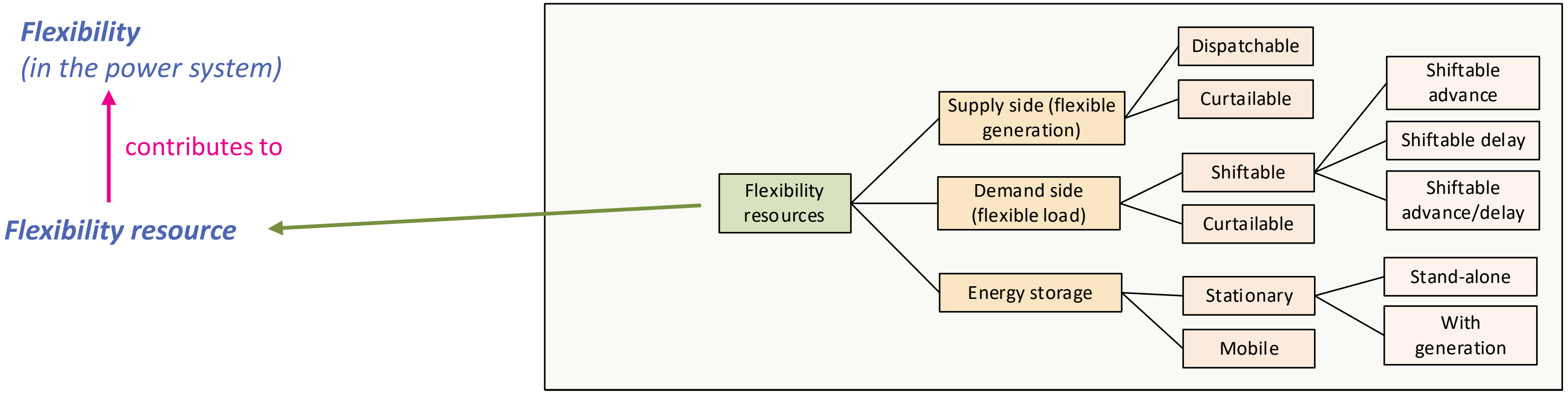
Flexibility
(in the power system)

contributes to

Flexibility resource

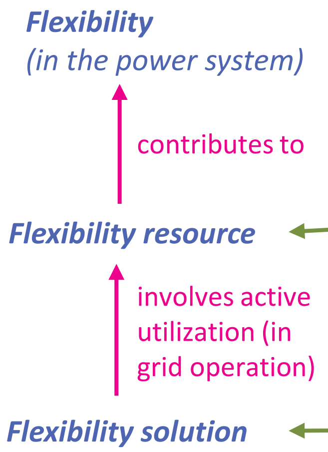
CINELDI definition: "*Flexibility* is defined as the ability and willingness to modify generation injection and/or consumption patterns, on an individual or aggregated level, often in reaction to an external signal, to provide a service within the energy system or maintain stable grid operation"

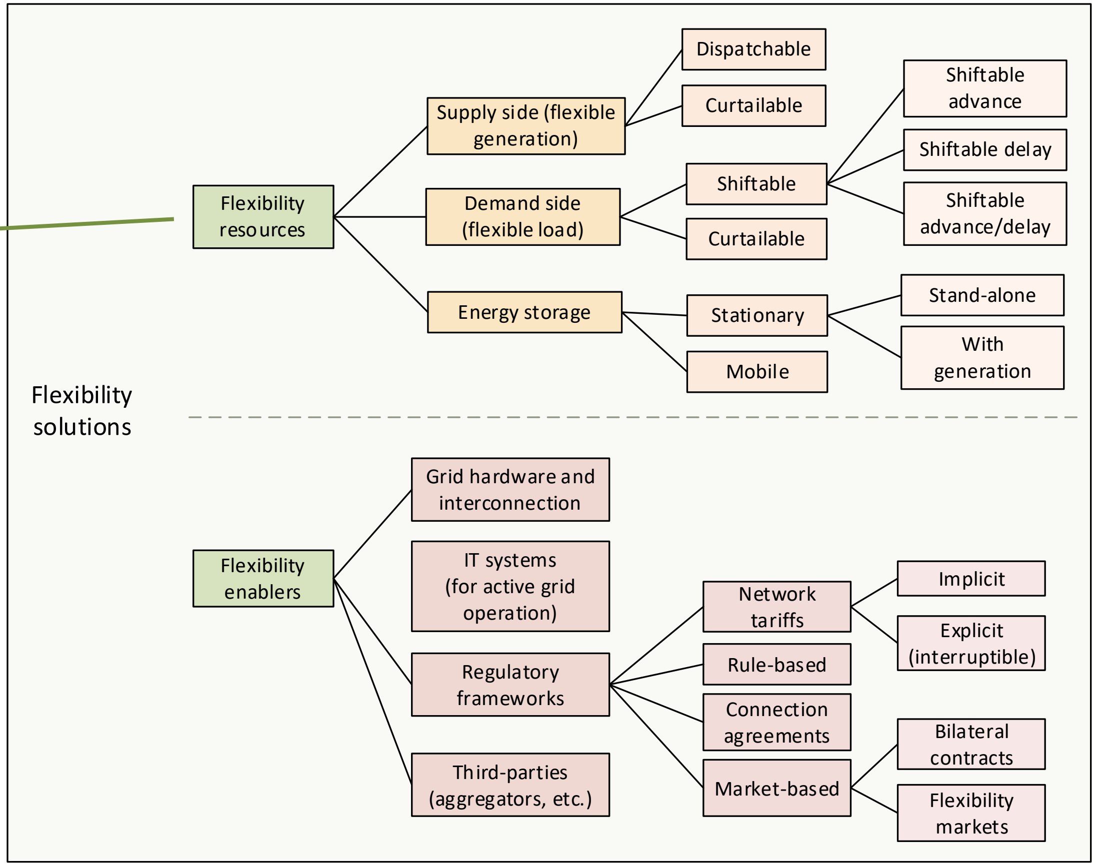
Classifying power system flexibility



For a review of *flexibility* definitions and flexibility resources, see also:
M. Z. Degefa, I. B. Sperstad, and H. Sæle, "Comprehensive classifications and characterizations of power system flexibility resources", *Electric Power Systems Research*, vol. 194, p. 107022, 2021. Available: https://doi.org/10.1016/j.epsr.2021.107022.

Classifying power system flexibility

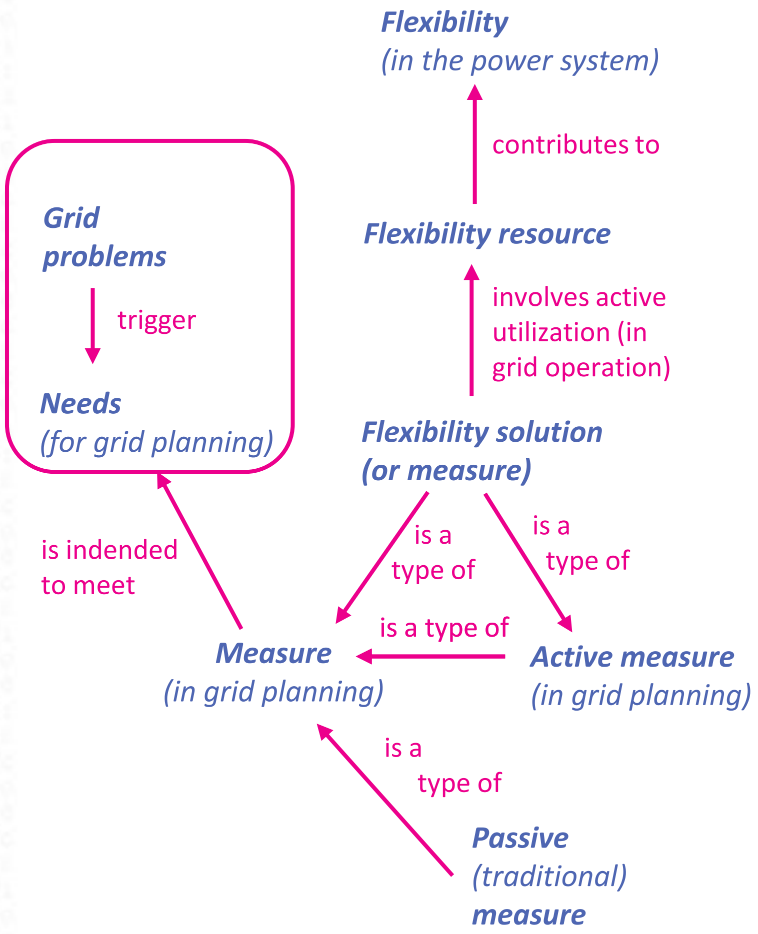


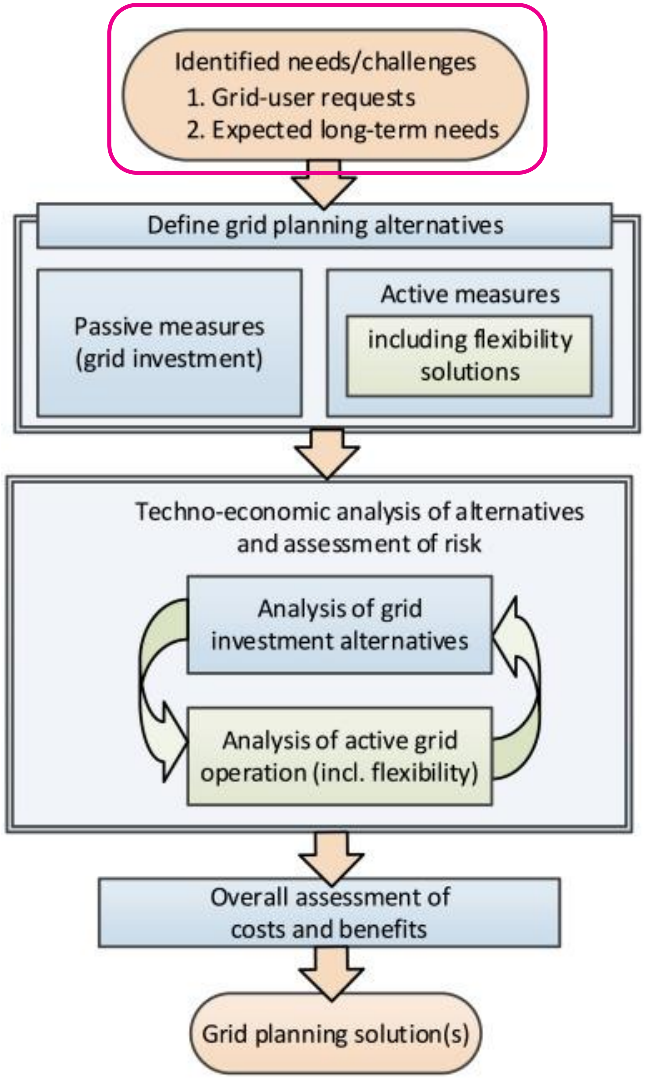


Source: H. Sæle, I. B. Sperstad, K. Wang Høiem, and V. Mathiesen, 'Understanding barriers to utilising flexibility in operation and planning of the electricity distribution system – Classification frameworks with applications to Norway', *Energy Policy,* vol. 180C, p. 113618, 2023, doi: [10.1016/j.enpol.2023.113618](https://doi.org/10.1016/j.enpol.2023.113618).

Why flexibility?

Framework for planning of active distribution grids (considering flexibility)





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Based on: I. B. Sperstad, E. Solvang, and O. Gjerde, "Framework and methodology for active distribution grid planning in Norway," *PMAPS 2020*, 2020. Available: https://hdl.handle.net/11250/2689734.

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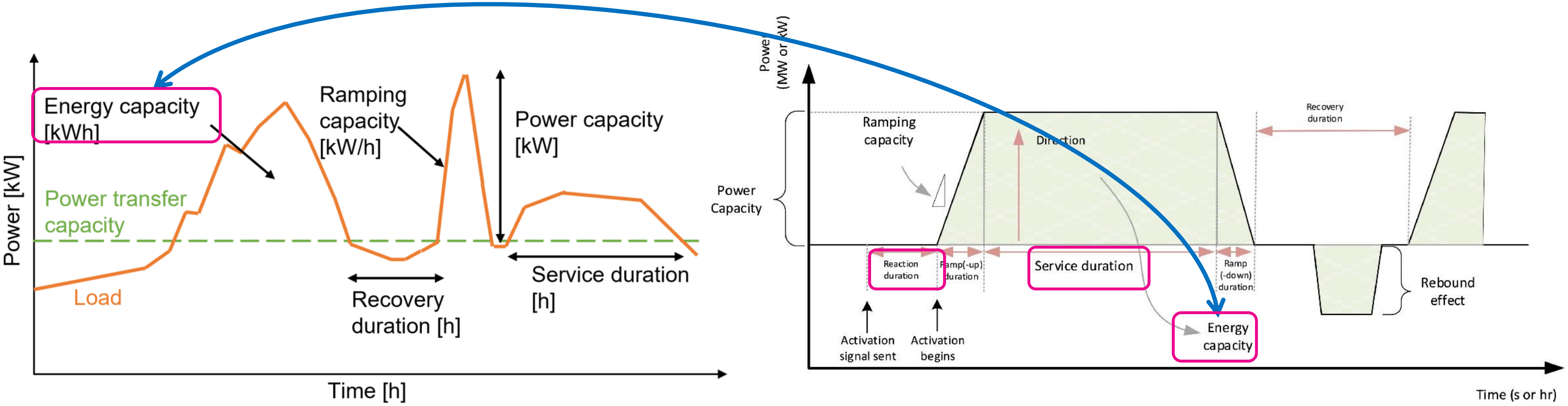
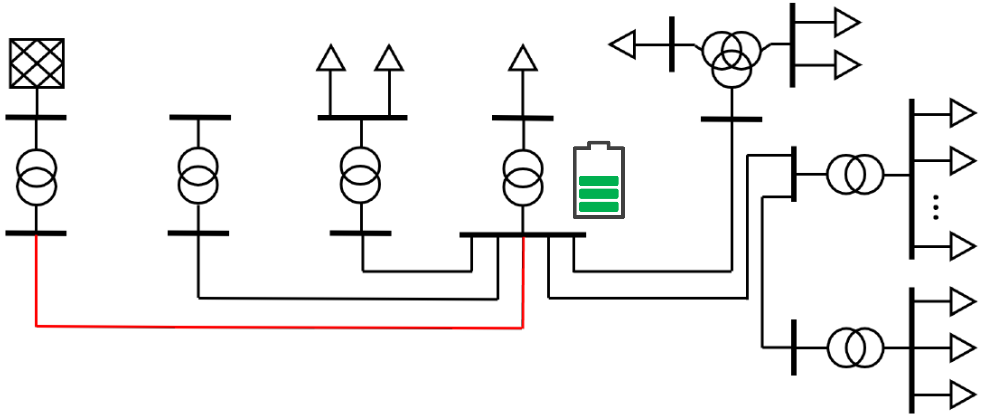
Matching flexibility needs to flexibility resources





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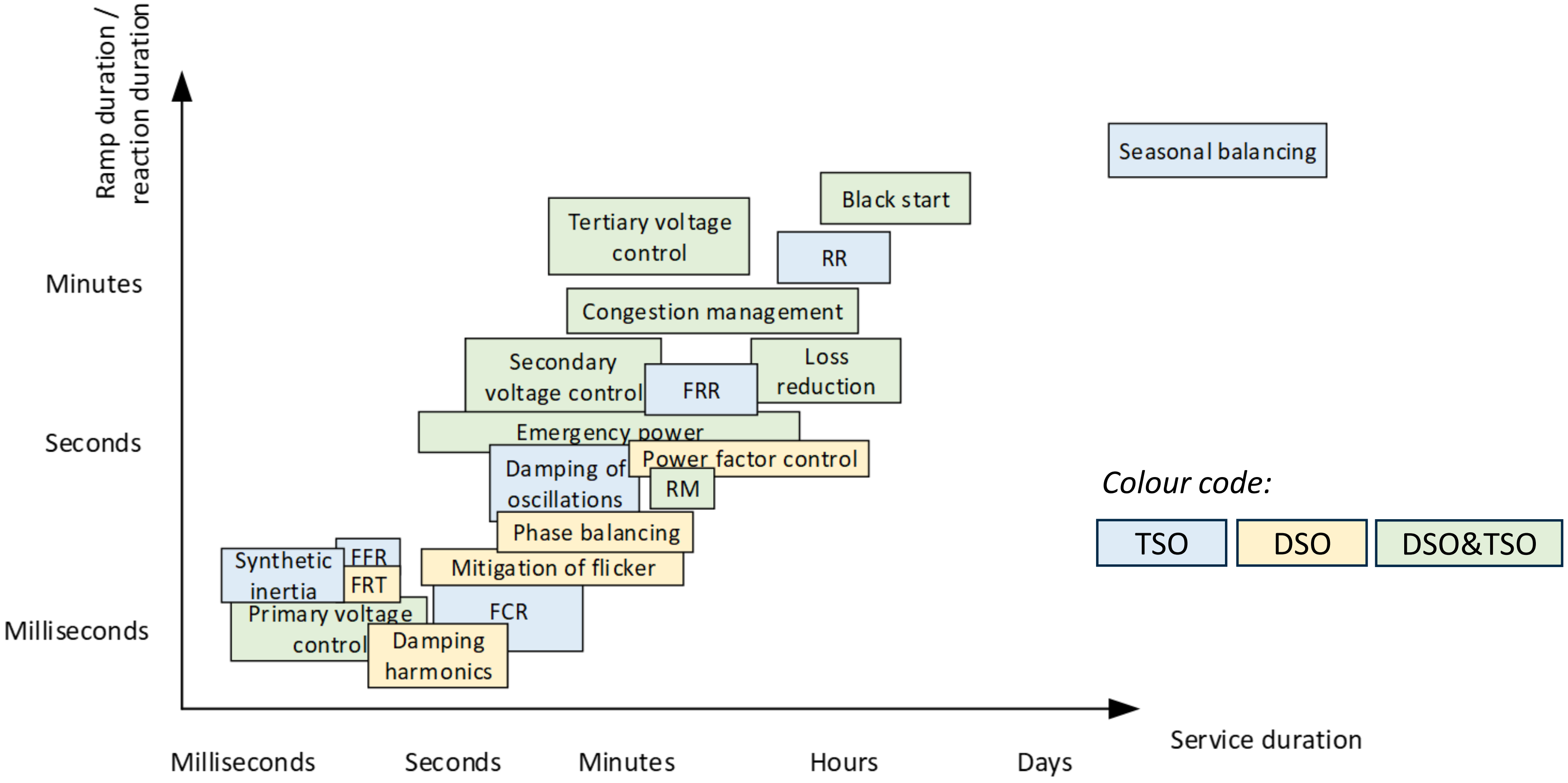
Flexibility services: Requirements for flexibility characteristics



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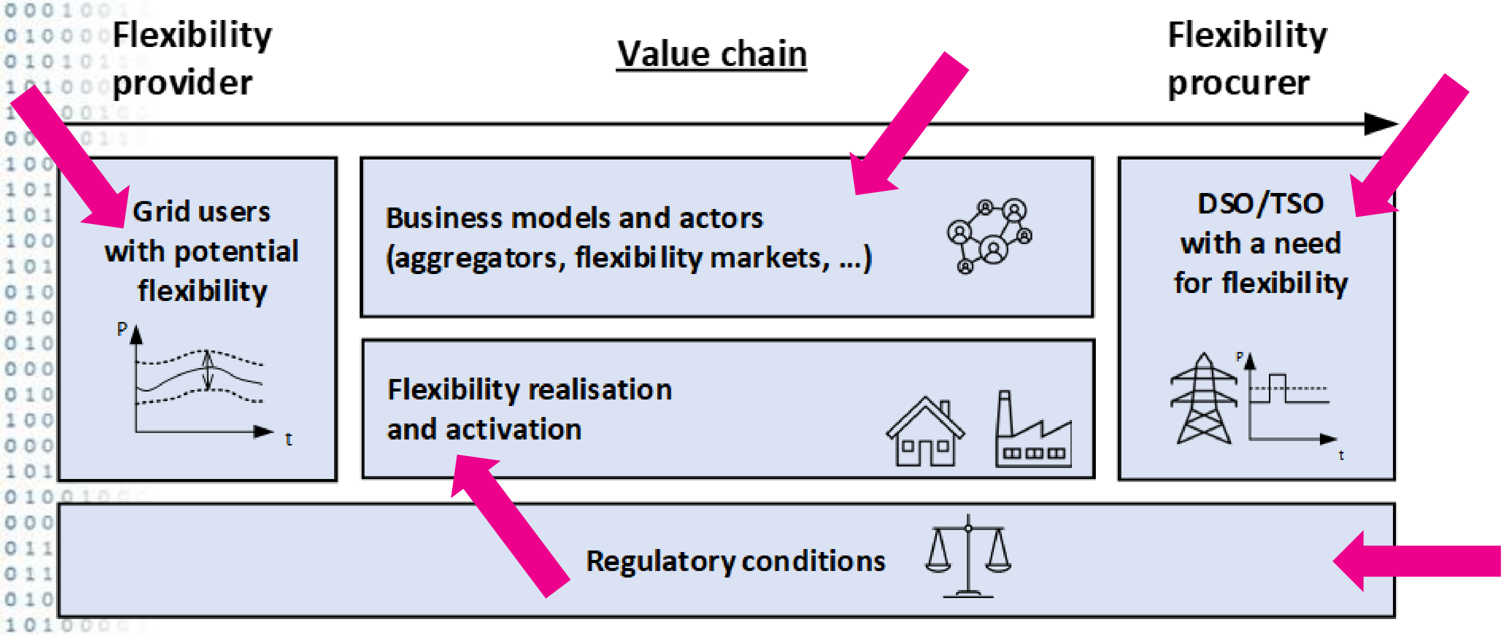
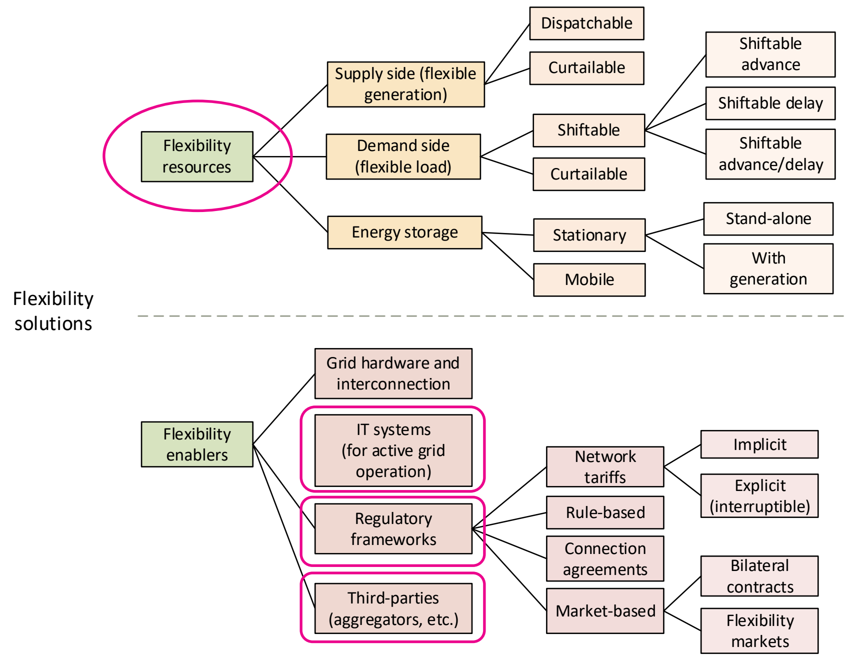
Why *not* flexibility?

Value chain and barriers for flexibility



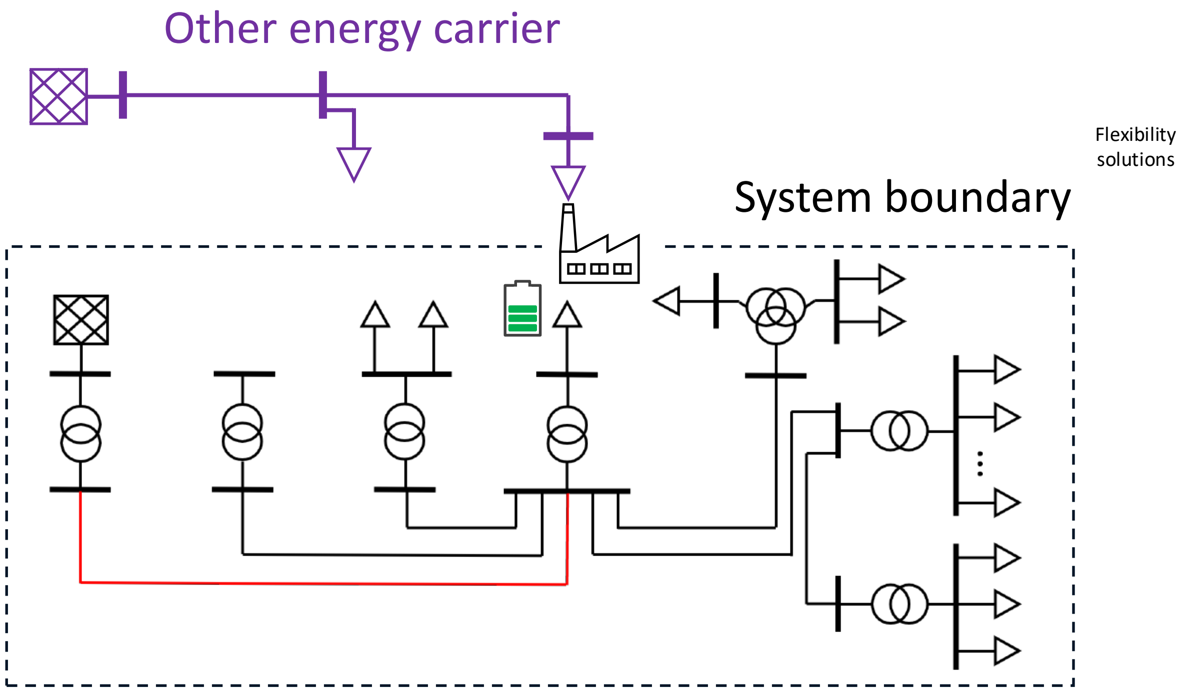


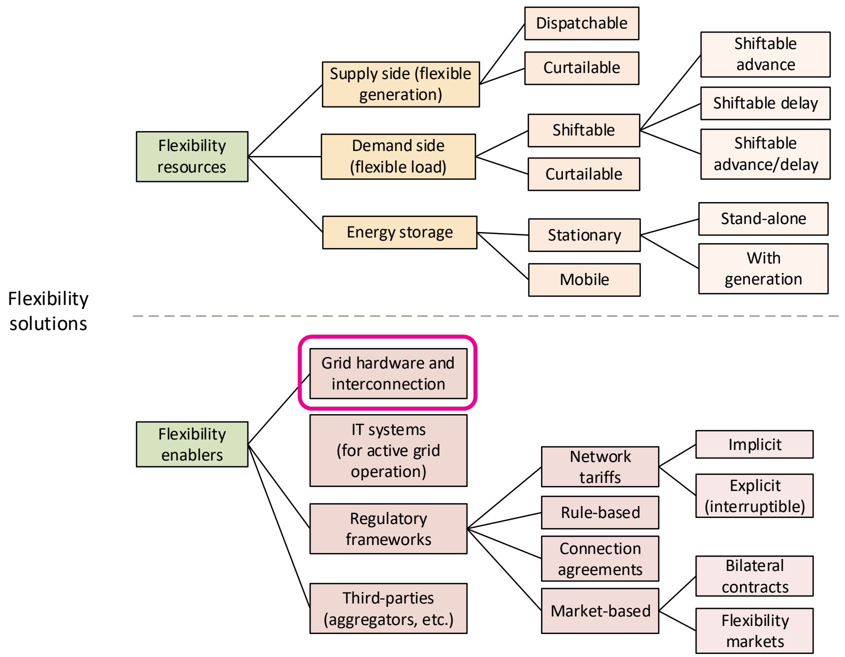
Technical barriers:

- Lack of connections between IT systems for grid operators and grid planners.
- Lack of information about actual capacity in the grid (and need for flexibility).

Source: H. Sæle, I. B. Sperstad, K. Wang Høiem, and V. Mathiesen, 'Understanding barriers to utilising flexibility in operation and planning of the electricity distribution system – Classification frameworks with applications to Norway', *Energy Policy*, vol. 180C, p. 113618, 2023, doi: 10.1016/j.enpol.2023.113618.

Sector-coupling and flexibility





Summary

- Describing “what-is-what” related to flexibility aids understanding and communication
- There are many ways to define, classify and characterize power system flexibility
  - depending on what perspective one takes
  - and how one sets the system boundaries
- One should consider what need a flexibility solution is intended to meet
- A flexibility solution encompasses both flexibility resources and enablers
  - Sector coupling and digitalization are enablers of power system flexibility

Selected references

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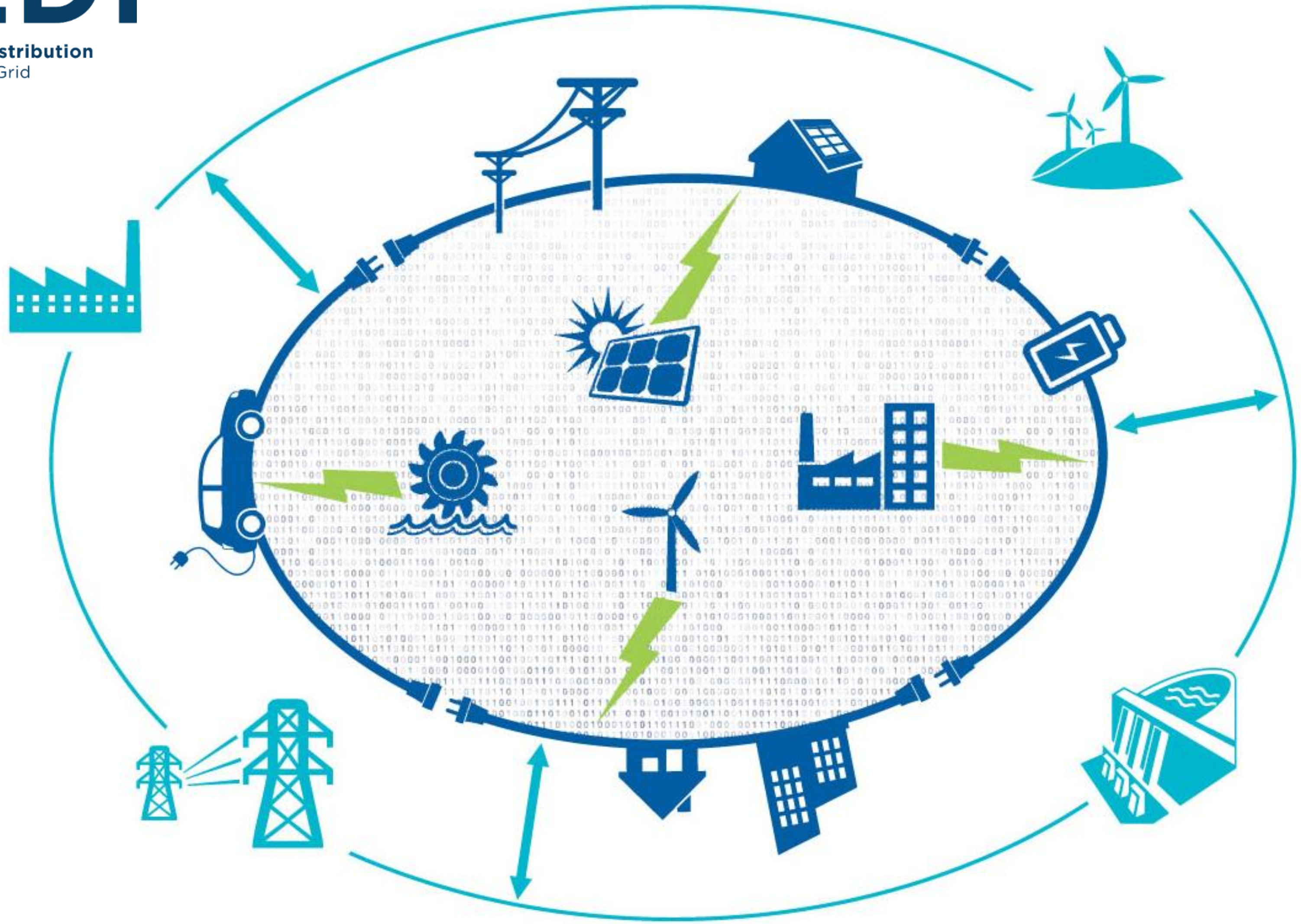

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