ALFEN

POWER TO ADAPT

BESS trends: importance of grid forming features

- Evert Raaijen,
- Business Development Manager Alfen Energy Storage Systems

Dutch Power 16 September 2025

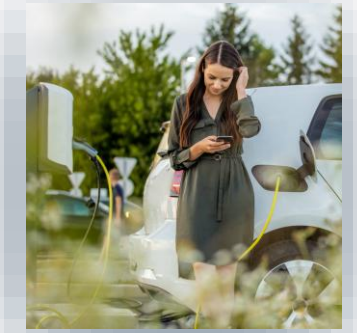
What’s next in Energy Storage?

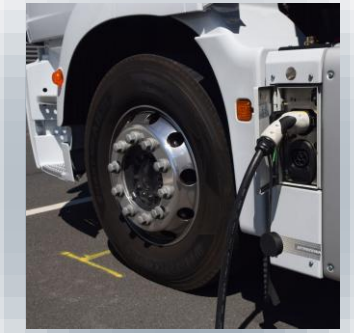
ALFEN
POWER TO ADAPT

How does a BESS look like

TREND 1

More consumption of electricity (load)

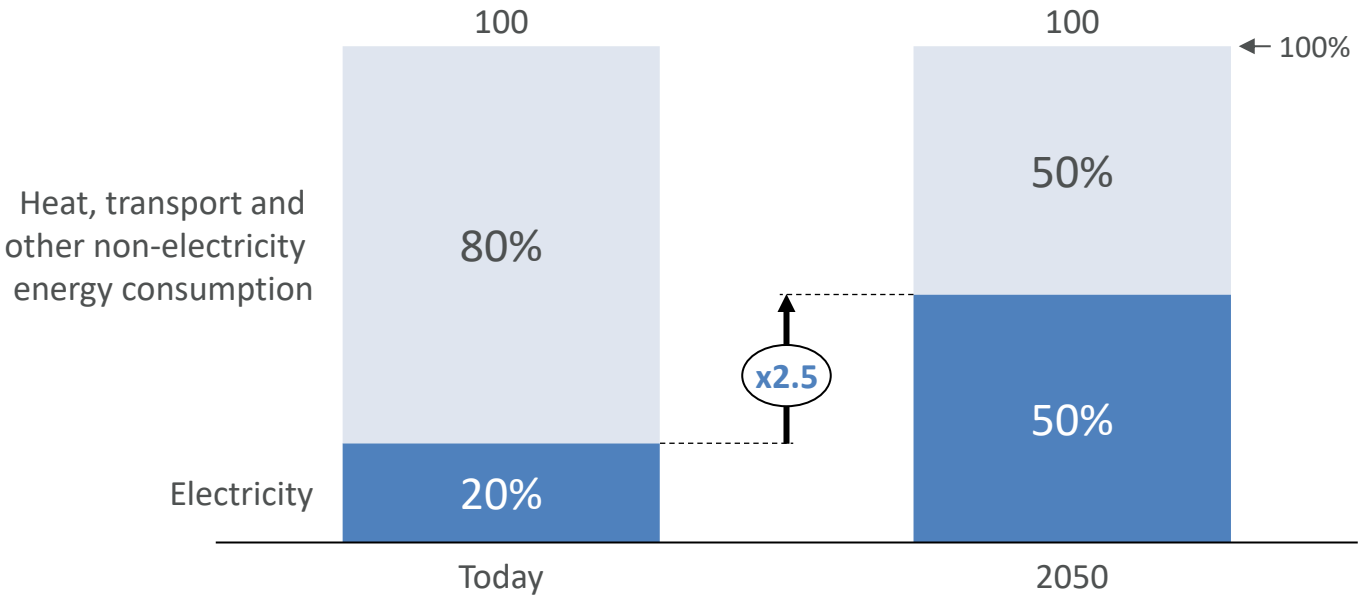




ALFEN
POWER TO ADAPT

Energy consumption is expected to shift to c.50% electricity by 2050, driving companies like Alfen long-term growth

Energy consumption

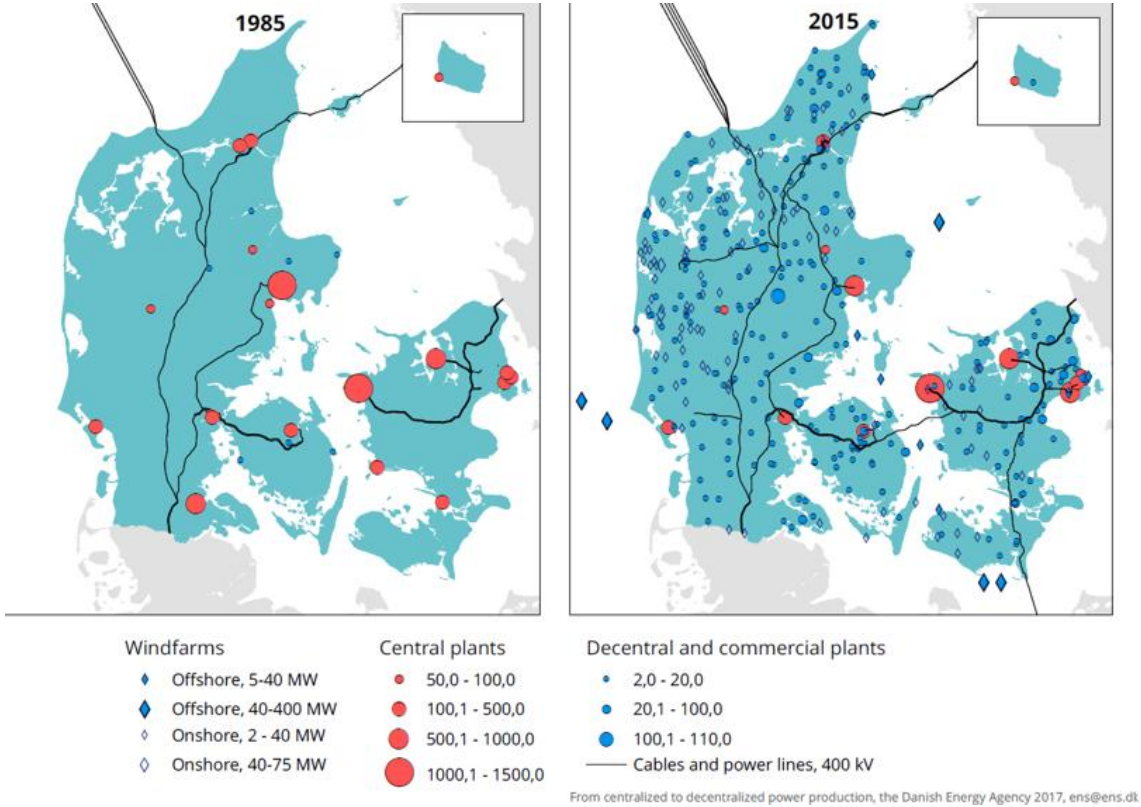


Source: IEA

ALFEN
POWER TO ADAPT

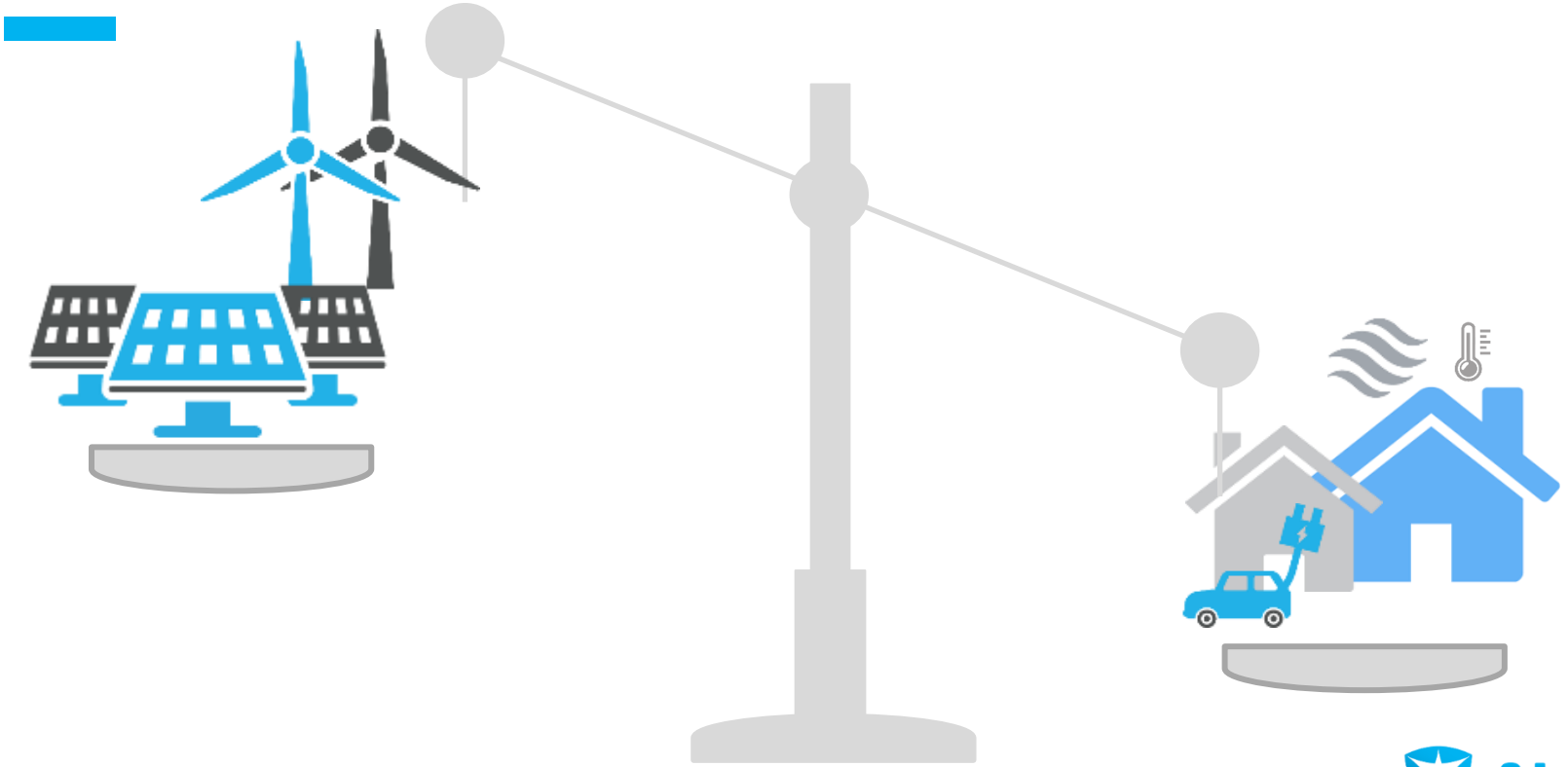
TREND 2

More uncontrollable renewables less controllable power plants



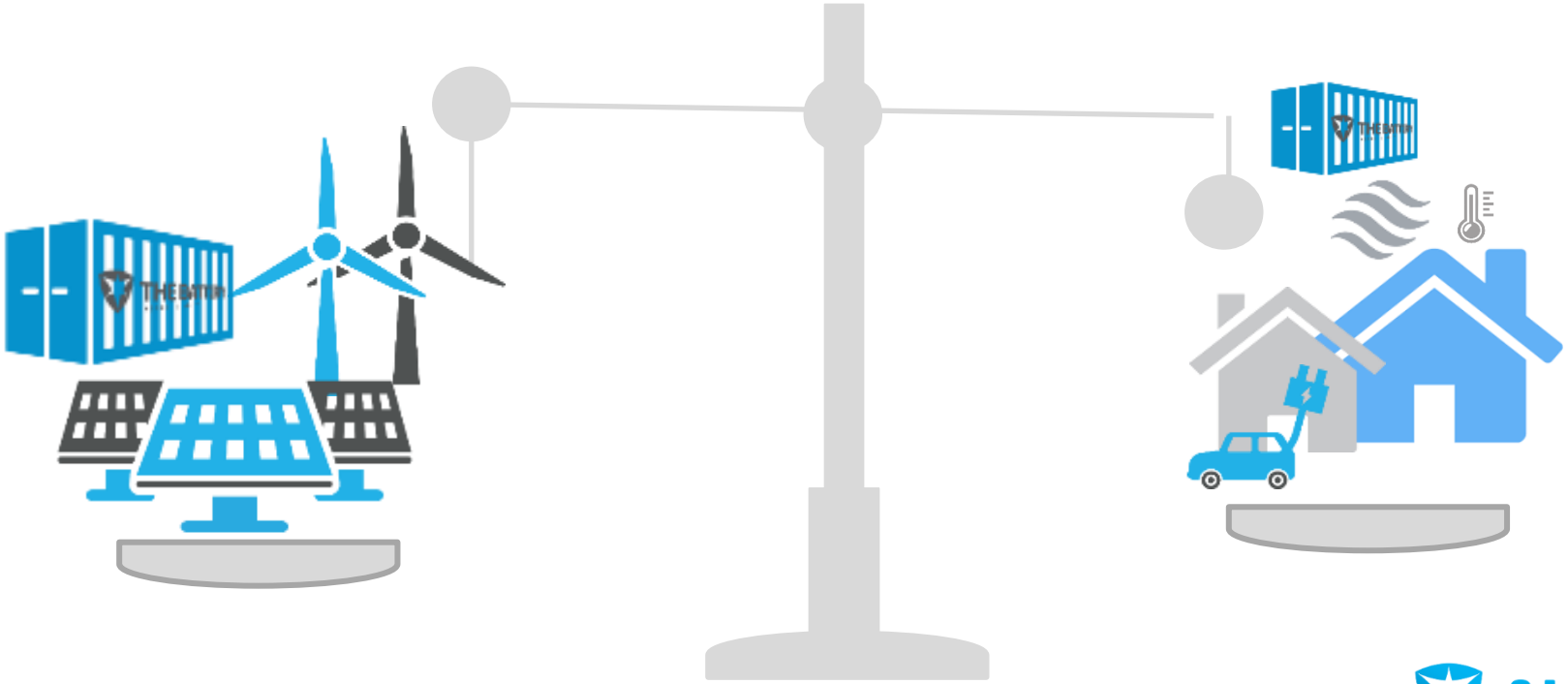
ALFEN
POWER TO ADAPT

Grid balancing is needed



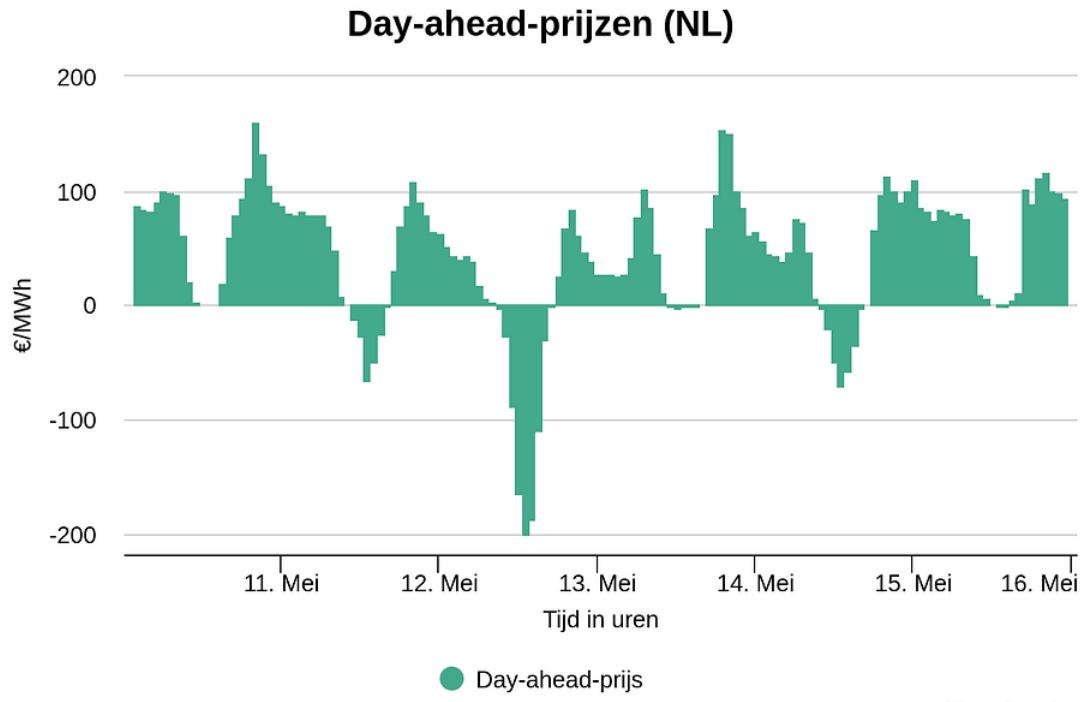
ALFEN
POWER TO ADAPT

Energy storage brings the grid in balance



TREND 3

(Dis)charge storage times increase from 1 hour to 2-8 hours



profiteia.io

ALFEN
POWER TO ADAPT

TREND 4

Capacity per project is increasing up to many 100 MW

ALFEN
POWER TO ADAPT

TREND 6

Battery storage at PV parks and wind farms

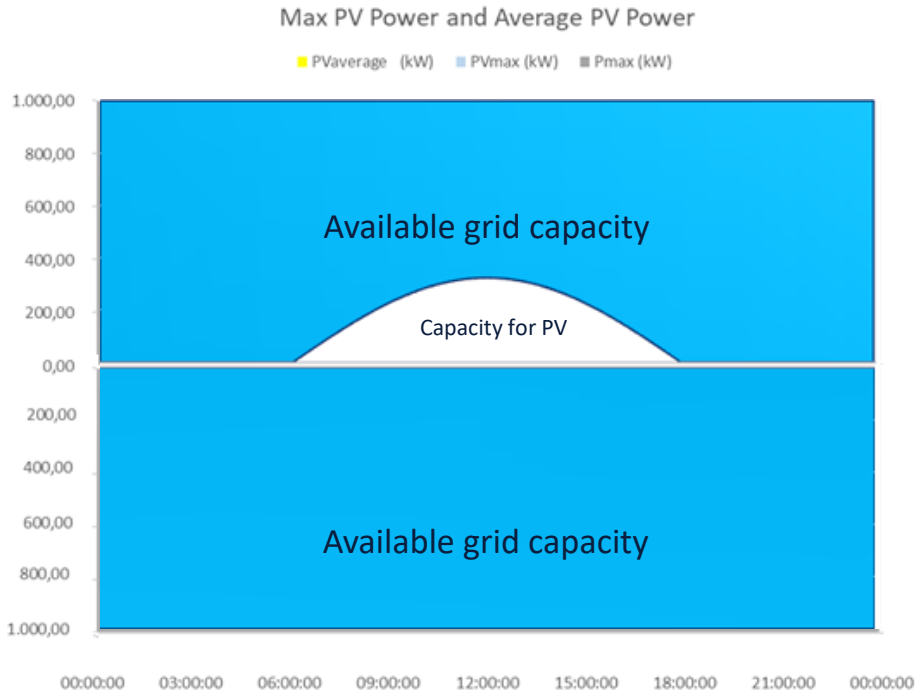
1. Avoids grid congestion
2. Reduces the curtailment of PV and Wind in case of overproduction
3. Lower initial and recurrent costs by grid connection sharing
4. Increasing PV and Wind on an existing grid connection
5. Option for gridforming function in case of grid failure (black start, next generation powerplant)
6. Available grid capacity due to low used capacity by Wind and PV, see next slide

ALFEN
POWER TO ADAPT

Available grid capacity at solar parks and wind farms

Example: available grid capacity for Energy Storage Systems:

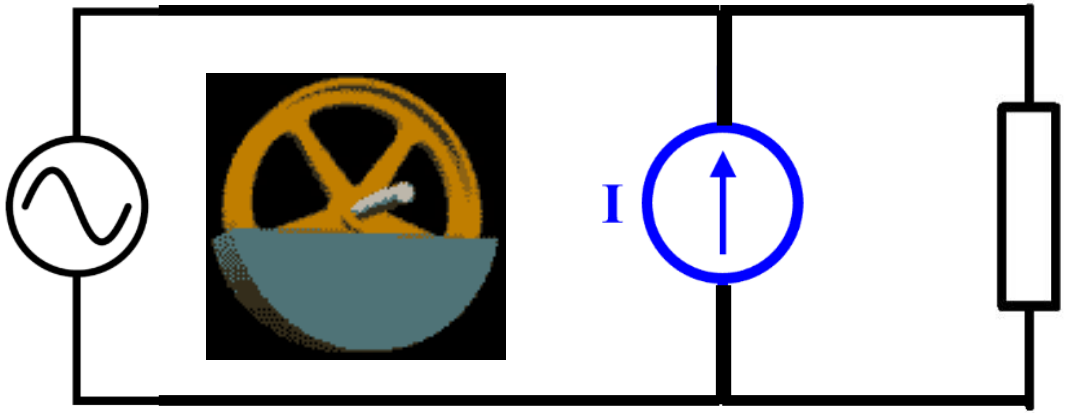
Available grid capacity %	Only export	Import & export
Using PV park connection	90%	95%
Using Wind park connection	60% - 80%	80% - 90%
Using PV- and wind-park connection	50% - 60%	75% - 80%



ALFEN
POWER TO ADAPT

Trend 7

Energy storage systems will be grid forming (voltage source with inertia)



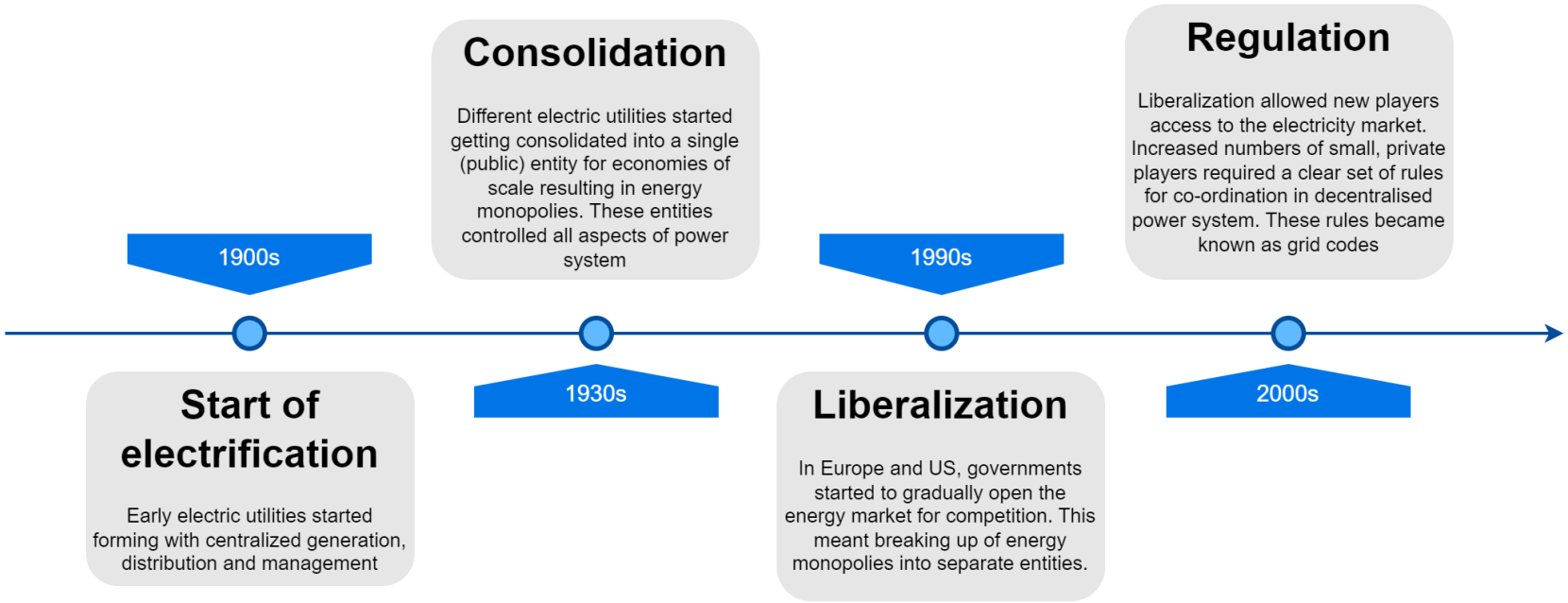
Conventional generation
Voltage sources (grid forming with interia)

Renewable generation
Current sources (grid following)

Loads

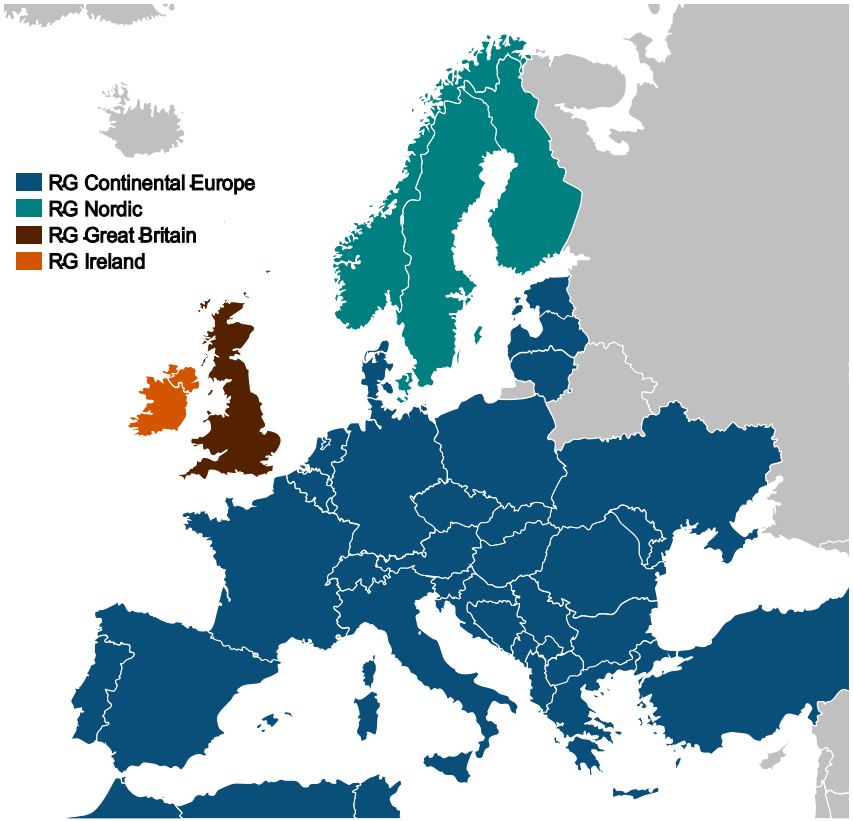
ALFEN
POWER TO ADAPT

History: Grid code and energy markets



ALFEN
POWER TO ADAPT

Grids of Europe (Regional Groups)

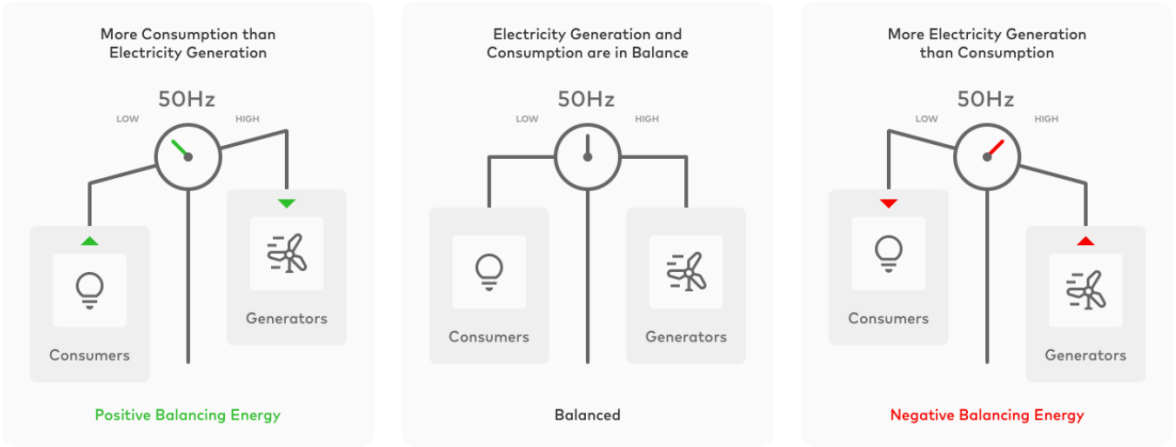


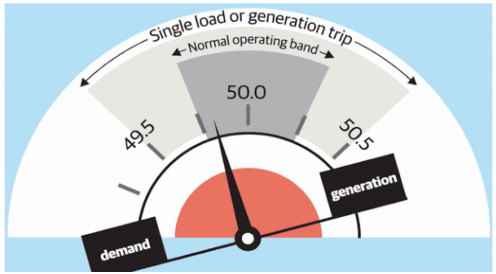
ALFEN
POWER TO ADAPT

Grid code requirements example: Belgium

Type D			
Type C			
Type B			
Type A			
Voltage withstand capability	Automatic reconnection	Active Power Controllability and Control Range	Voltage withstand capabilities
Frequency withstand capability	Fault-ride through	Frequency Sensitive Mode (FSM)	Fault-ride through
Rate Of Change Of Frequency (RoCoF) withstand capability	Reactive capabilities	System restoration	Resynchronization
Limited Frequency Sensitive Mode (LFSM)	Fault Current & dynamic voltage support	Reactive capabilities	
Automatic connection	Post-fault active power recovery	Voltage control	

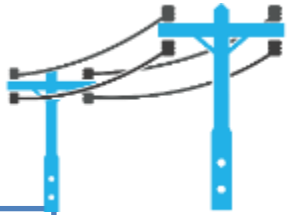
A Delicate Balancing Game

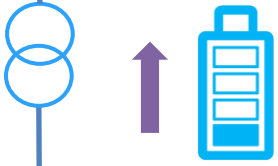




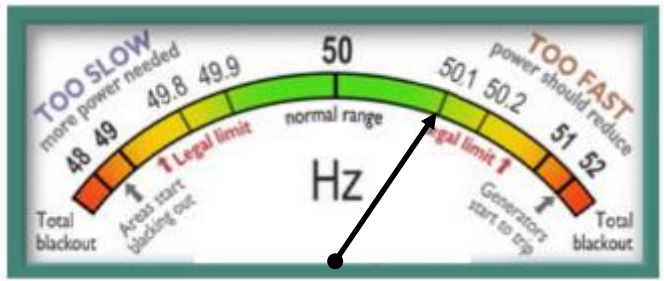
ALFEN
POWER TO ADAPT

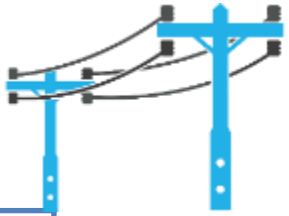
Frequency response applications

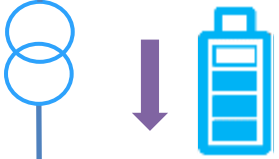




Frequency response applications



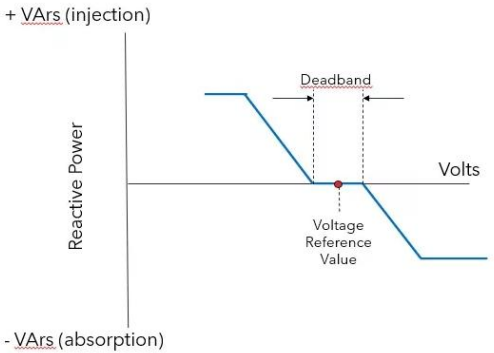




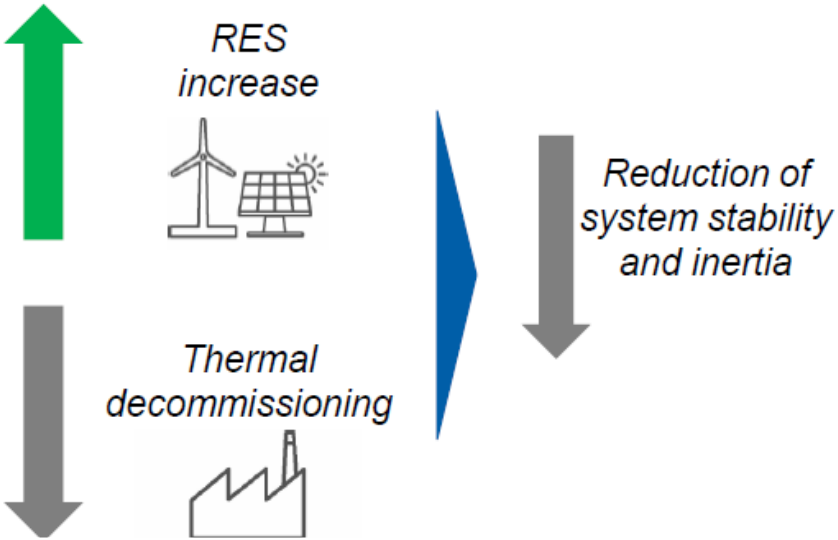
Typical reaction times 1-30 seconds

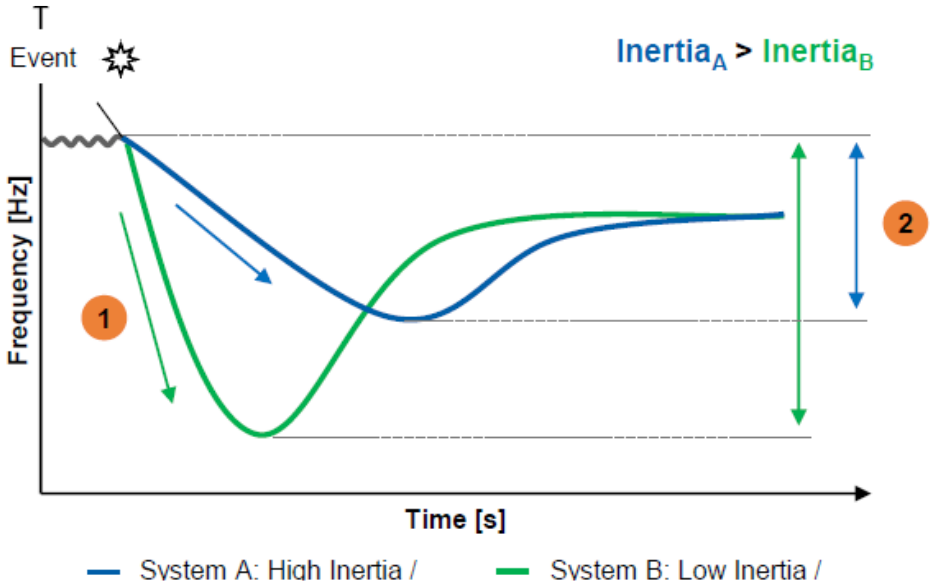
Several other features were added to the grid following inverters

- Reactive power / voltage control:
  - Injecting reactive power to stabilize the voltage on a mainly inductive transmission and distribution grid
- All kind of withstand capabilities:
  - High voltage, low voltage ride through
  - Frequency change capabilities
  - Etc
- All kind of other functions:
  - Automatic reconnection
  - Resynchronisation
  - System restoration
  - Etc



EFFECTS OF INCREASING RENEWABLES ON SYSTEM STABILITY





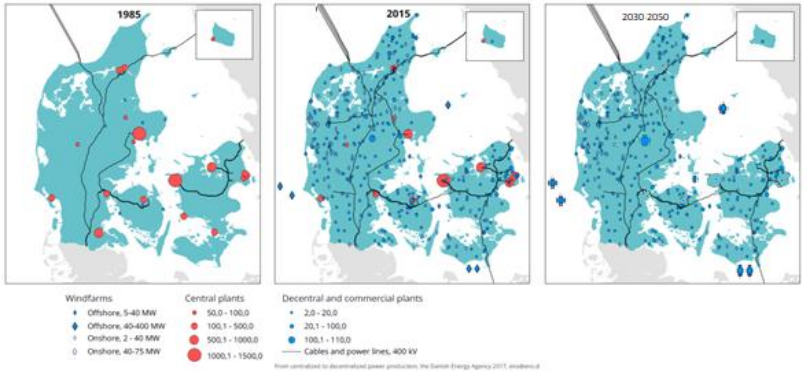
Inertia: power = constant * df/dt

- Lack of inertia will give unstable grid, especially with current huge amounts of grid following inverters and reducing conventional inertia.
- Lack of inertia is a contributing factor of the 28th April 2025 Iberia Incident.

Future grid forming inverters are required

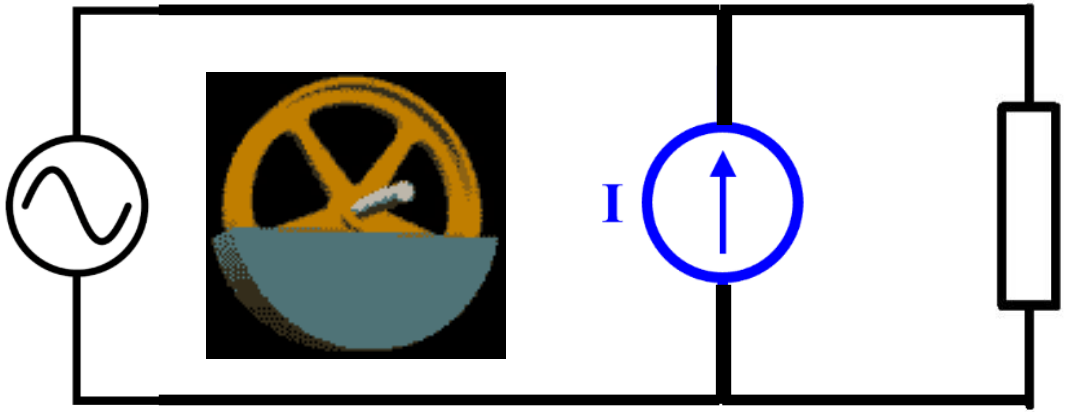
Trend:

- 2030-2050: much less (or no) conventional powerplants
- PV and Wind power is intermittent
- BESS power is constantly available



- Grid following inverters even with gridcodes will not keep grid stabile because of lacking voltage control and inertia
- Grid code compliant grid forming inverters are required, and BESS power is constantly available (contrary to PV and Wind)
- Several countries are working on grid forming requirements in the gridcode:
  - Finland, Belgium, Italy, Australia, China, USA

Energy storage systems will be grid forming (voltage source)



Conventional generation
Voltage sources (grid forming)

Renewable generation
Current sources (grid following)

Loads

- **We see the following trends:**
- Less conventional power plants (trend 2) → lack of voltage sources/inertia → grid instability (voltage and frequency)
- Energy storage systems can give the required voltage source and inertia performance
- Energy storage systems can do black start functionality in case of a grid blackout

ALFEN
POWER TO ADAPT

Combining the trends

1. Energy storage systems are required to balance the generation and consumption of a sustainable electricity grid (trends 1 and 2)
2. The energy storage systems increase in size (MW) and duration (trends 3 and 4)
3. Lithium storage is the winning storage technology (trend 5)
4. Combination of Energy storage systems with solar and wind parks are optimum solution (trend 6)
5. Energy storage systems will be grid forming (voltage source) (trend 7)

Conclusion:

Conventional powerplants will be replaced by large 2-8 hour lithium ion energy storage systems co-located at solar and wind parks with gridforming voltage source characteristics including the ability to black start the electricity grid.

Thanks for your attention !

Questions?