Energy Flexibility in the NL low voltage grid

KIVI E Lunch Webinar 18 June 2025

BAS HUIJBRECHTS

TNO DIGITAL TRANSITION ENERGY SYSTEMS

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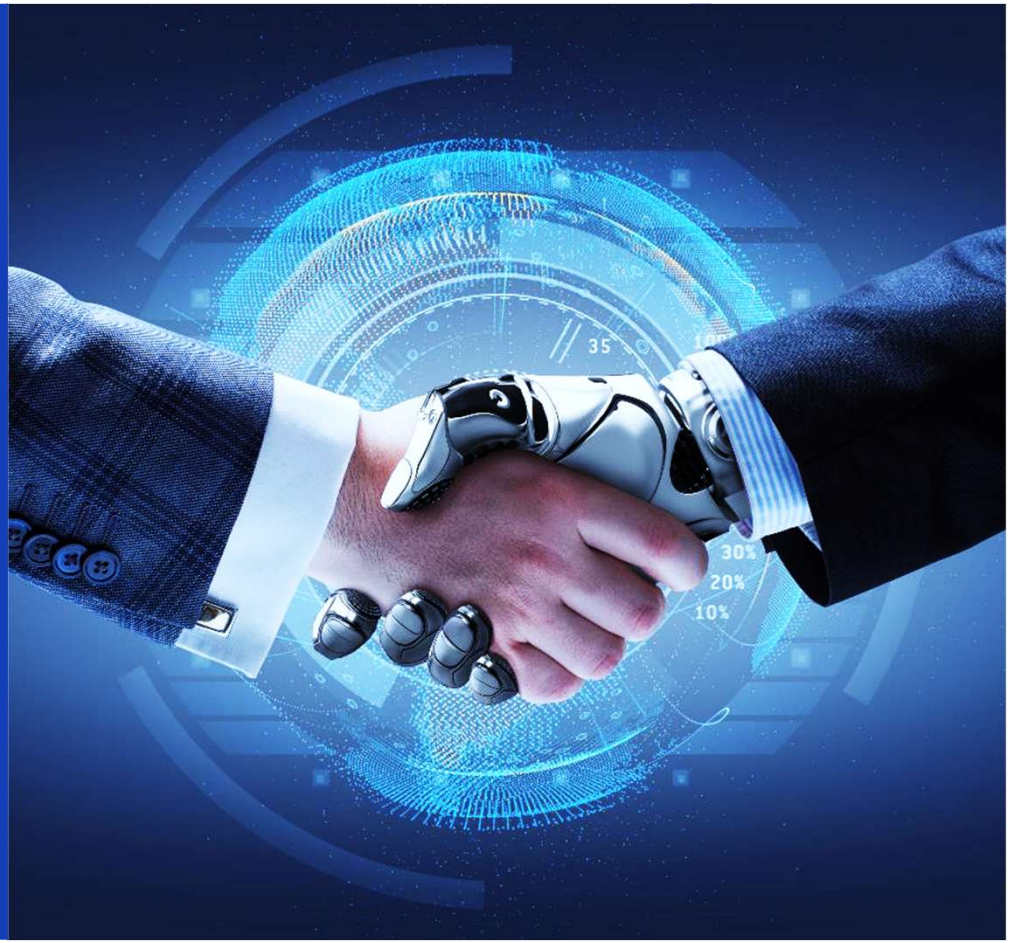
We are TNO

The Dutch organisation for applied research

Our mission is to create impactful innovations for the sustainable wellbeing and prosperity of society.

Digital Transition Energy Systems supports the NL energy ecosystem to fully benefit from digitalization.



Outline

Changing energy landscape

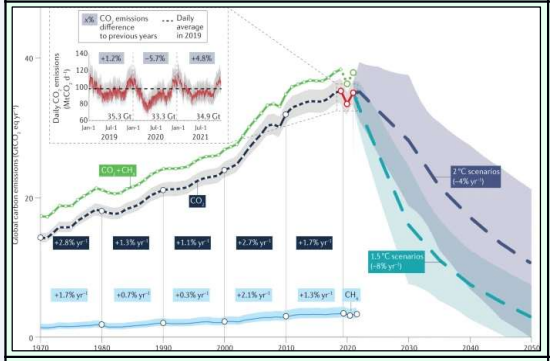
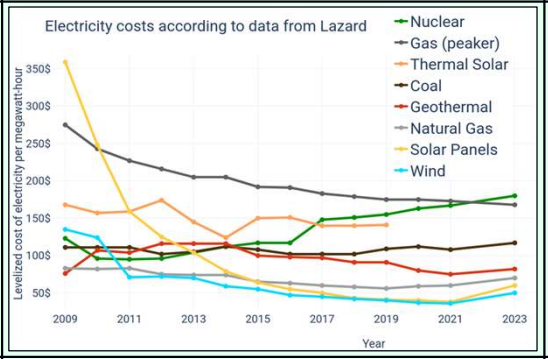
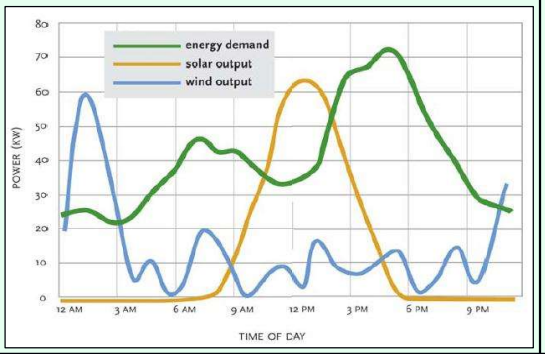
- grid congestion
- grid capacity expansion
- collective ownership
- digitalization

Energy Flexibility

- the flex measures pyramid
- unlock & control the flex potential
- tariffs to intensify unlocking of flex
- flex markets
- demand-side matching
- energy sharing & P2P trading

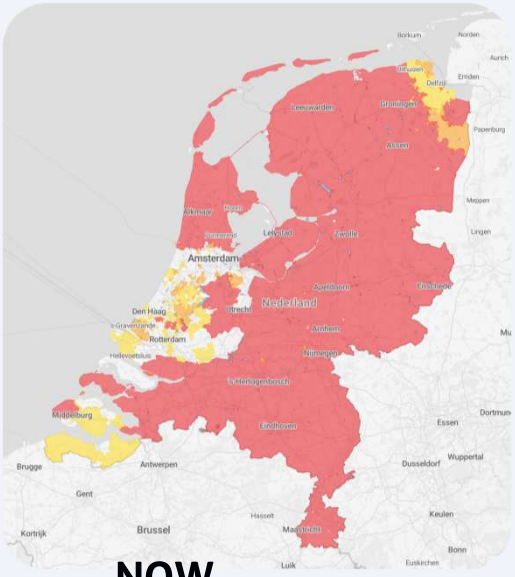
Wrap-up

Key drivers energy transition and their consequences

Climate goals	Economic	Intermittent & unpredictable supply	Massive electrification
			
• CO_2 reduction targets -55% (2030) → -100% (2050) • phase-out fossil fuels • shift to renewable sources • efficiency increase	• solar & wind cheaper than gas or coal power plants, OPEX → CAPEX • levelized cost of electricity • geopolitical dependencies	50% electricity solar/wind paradigm shifts: • demand → supply driven • flexibilization of energy supply	• EV's, heatpumps, industry, … • Up to 5x increase in electricity demand in 2050 • Smarter use of infrastructure

unprecedented engineering effort in tight labor market and expert scarcity

NL grid congestion building up fast



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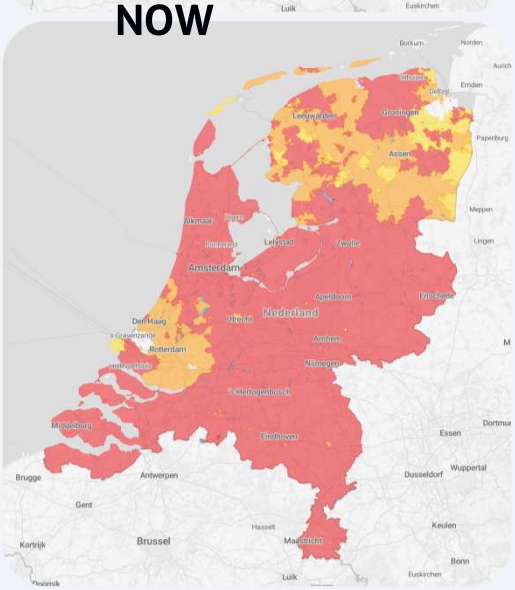
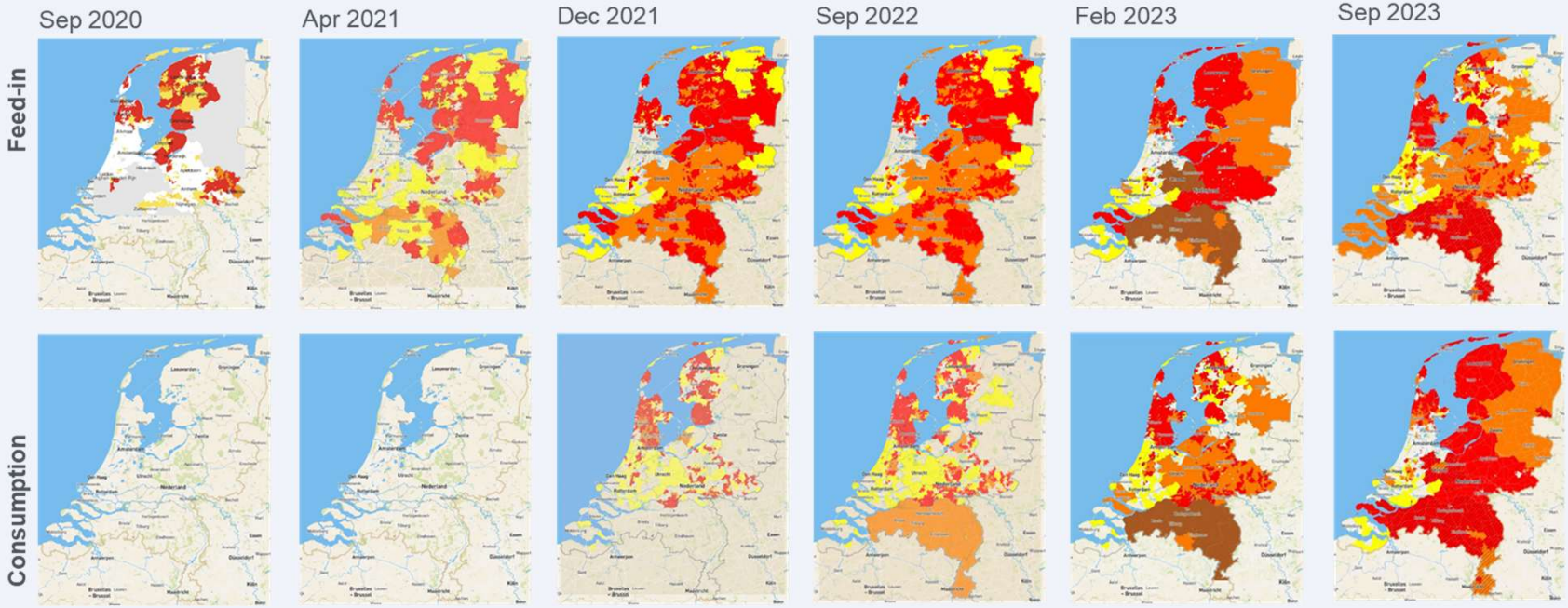


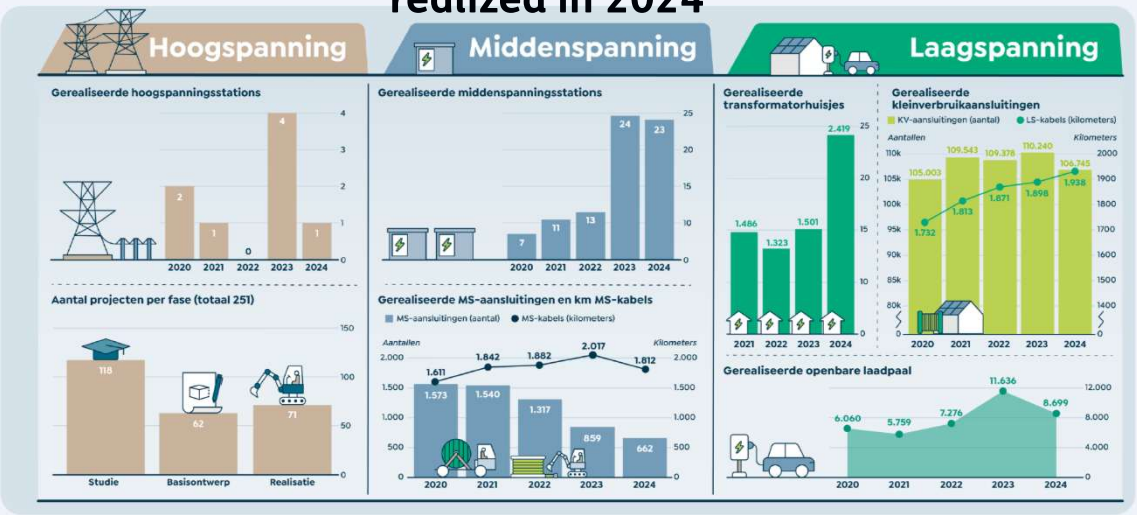


Netbeheer Nederland capaciteitskaart.netbeheernederland.nl

TNO innovation for life

Ongoing ‘radical’ grid capacity expansion

realized in 2024



extra infra needed until 2050

50.000+
transformatorhuisjes

670+
hoog- en middenspanningsstations

100.000+
km kabels

>30.000
extra technici tot 2030

>11.000
voetbalvelden ruimte

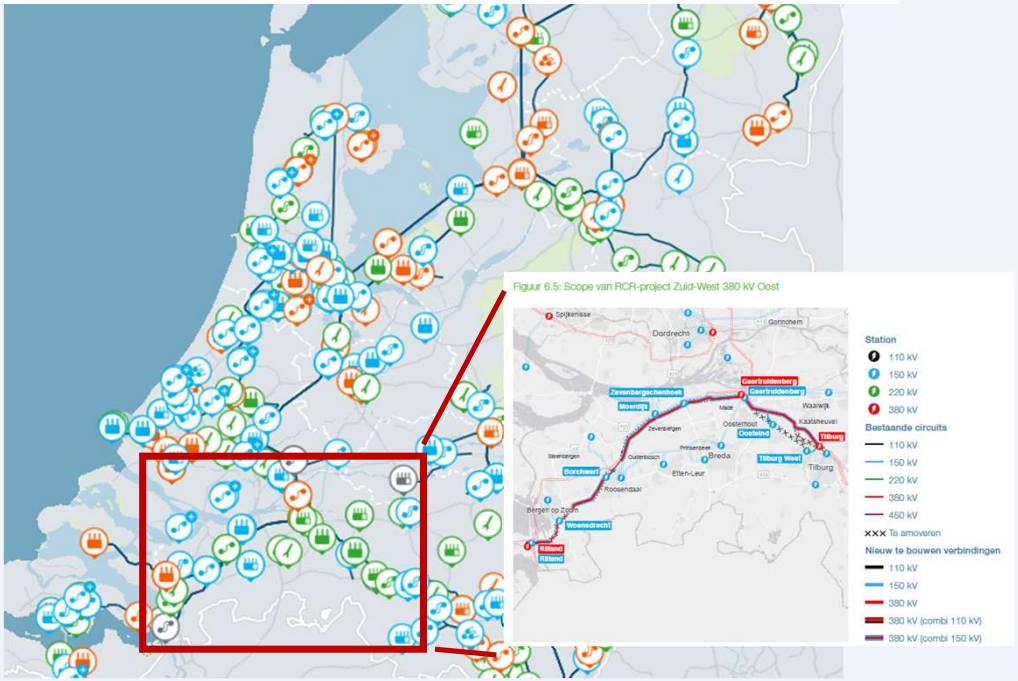
3 times more productive, much larger volume

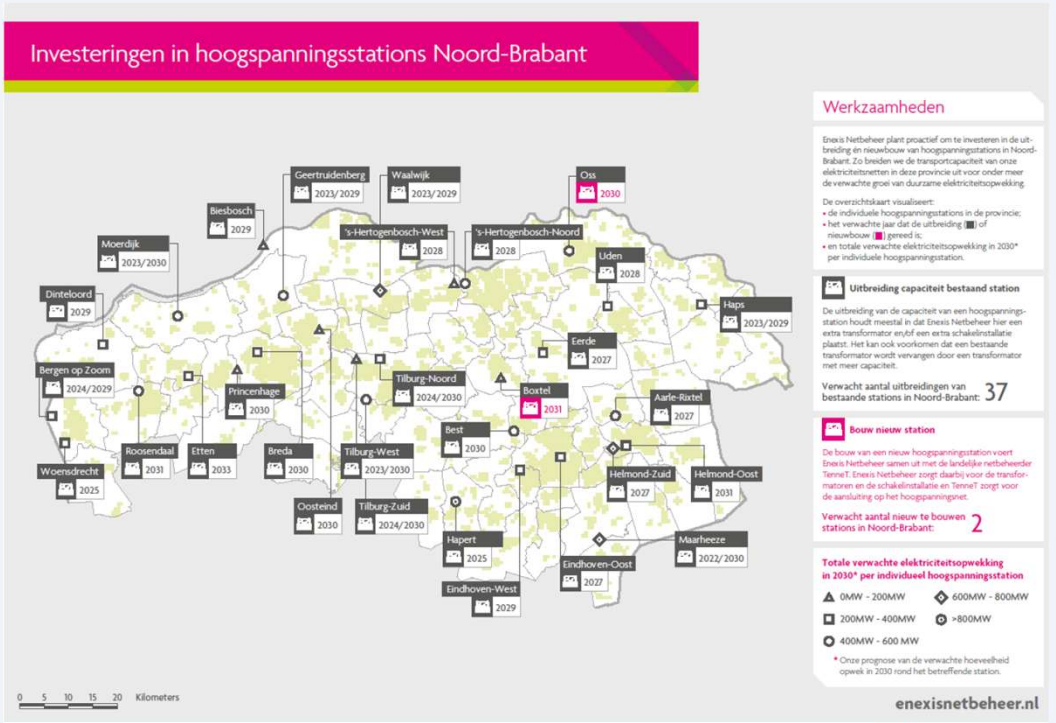
Reinforcement challenge

TenneT

“We can no longer afford to work at a pace of ‘bottleneck by bottleneck’”

- More than 350 locations with infrastructure projects
- Do 3 times more work with twice as fast project execution





Reinforcement challenge

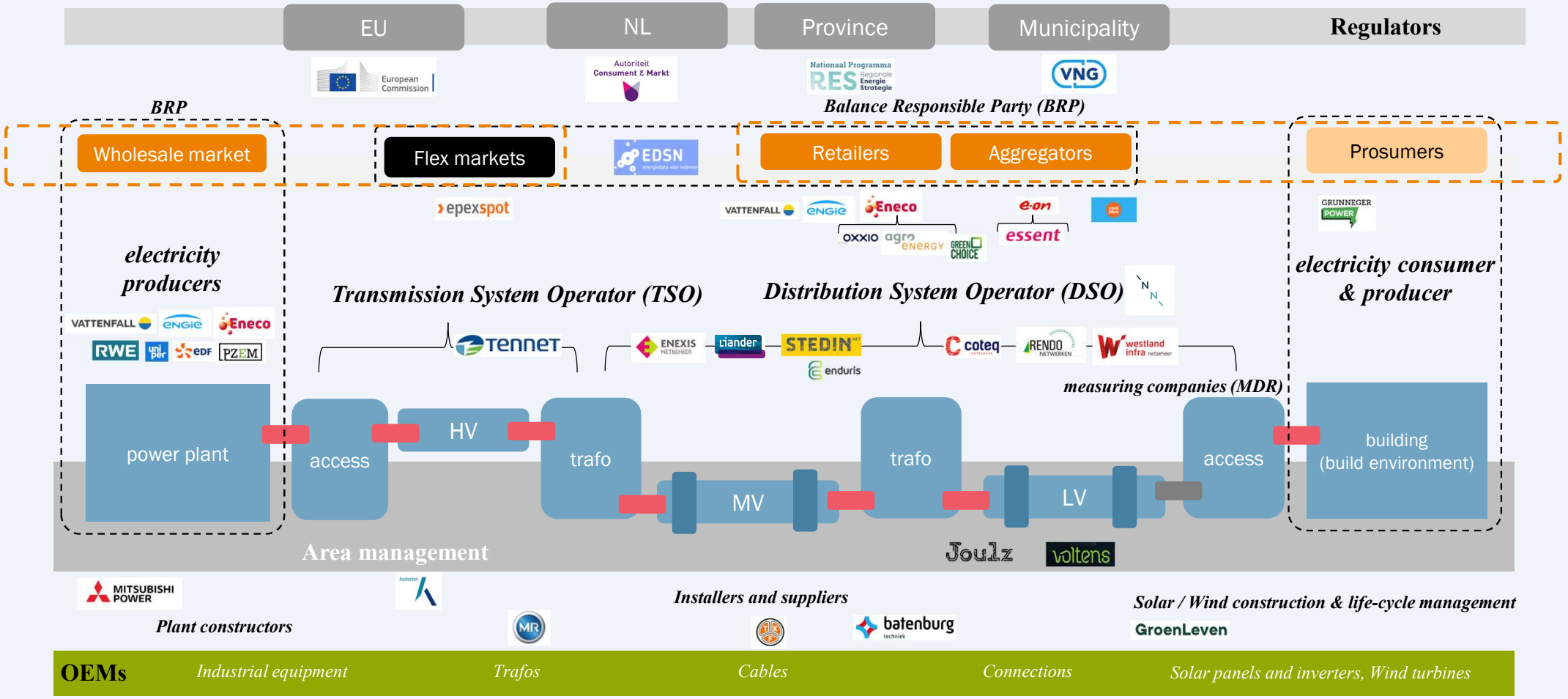
ENEXIS NETBEHEER

“Double in 10 years what was created in 100 years”

- From 10 mid-voltage stations per year to 120 per year
- From 1 year construction time to 13 weeks

Key grid operator challenges:
1 **land**, 2 **permission**, 3 **severe shortage of qualified personnel**

Collective ownership



NL electricity infrastructure

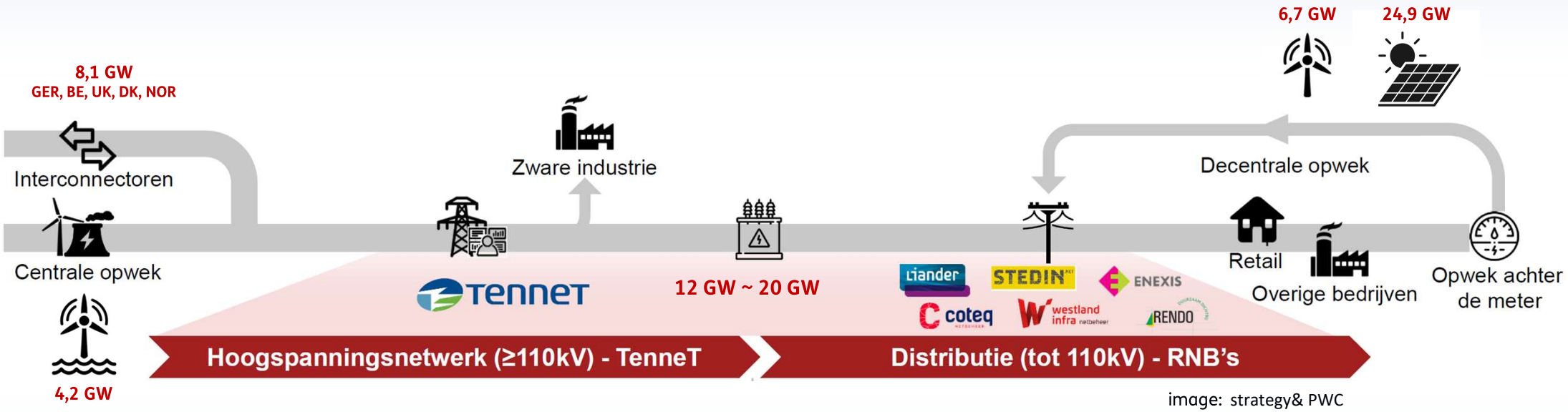
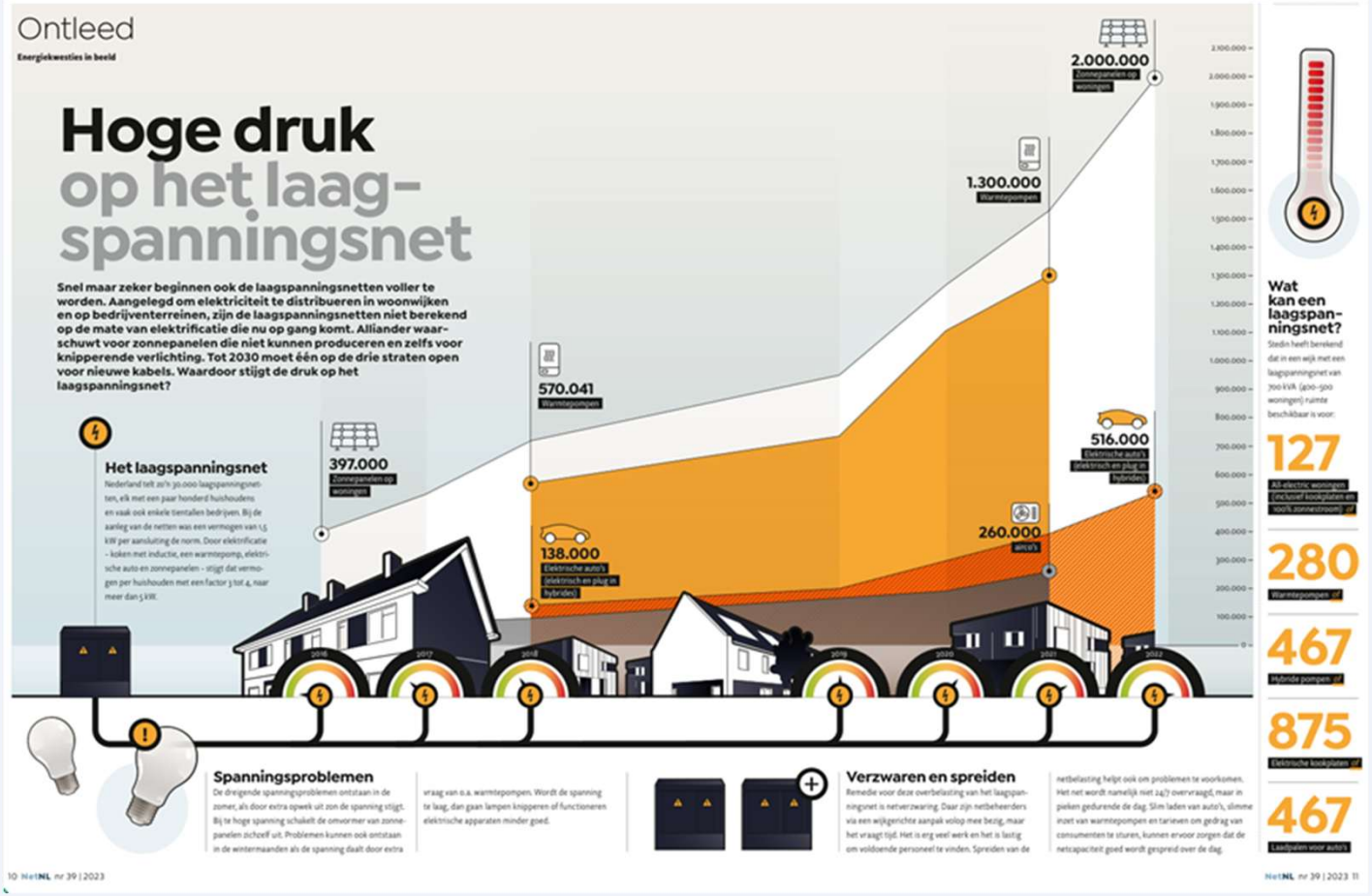


image: strategy& PWC

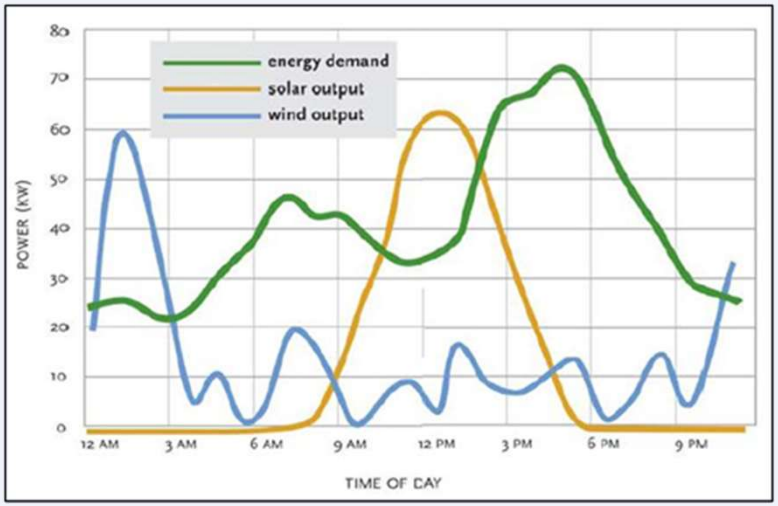
Need for capacity measures on the NL low voltage grid

- Every house has a connection peak capacity of either **8,1 kW** (1 phase) or **17,3 kW** (3 phases)
- Climate transition goals lead to electrification of heating & cooling, cooking, and mobility
- The expected average energy demand of an all-electric house is at least **5 kW**
- On average per house **1,5 kW** capacity is available which is fed by a 700 kVA trafo (400-500 houses), only sufficient for 127 all-electric houses

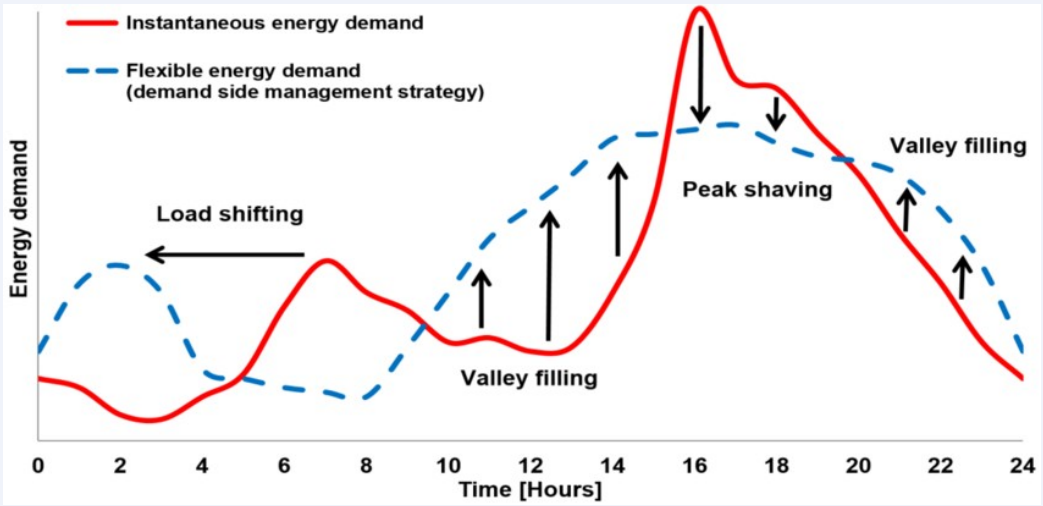


source: Het laagspanningsnet in cijfers, bron: NetNL nr 39, nov 2023

Digitalization, energy flexibility as alternative for full grid reinforcement



demand-side matching - grid balancing



effective use of grid - grid congestion

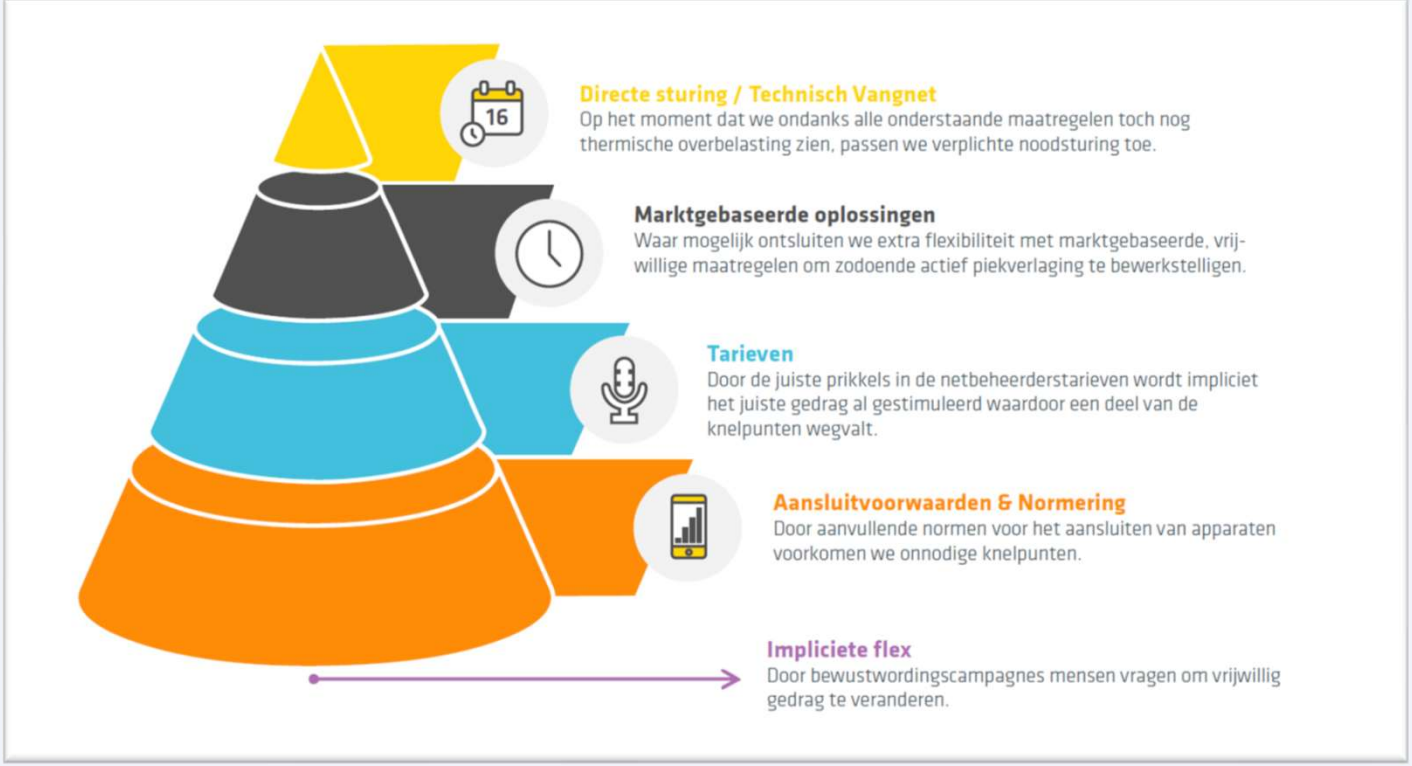
In addition, digitalization enables:

- Smart grid control and grid recovery (grid stability)
- Collaborative / distributed system approach
- Smart optimization of energy carriers mix
- Insights for consumer control & comfort
- New business / service models, making energy transition a source of profitability
- Swift adaption to emerging needs, trends and policies

Flexibility pyramid LAN LS: measures for low voltage grid

Layered - from passive to preventive to reactive - flexibility approach, with increasing impact for end-consumers:

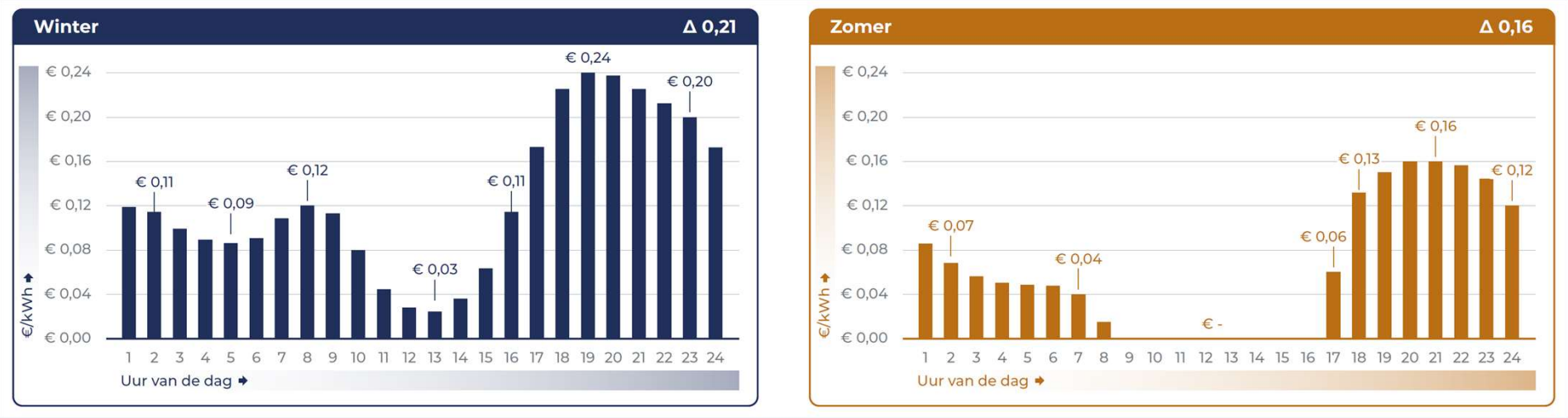
1. increase awareness to trigger behavioural change: avoid unnecessary simultaneously energy usage
2. enforcement (norming) of appliances
3. tariff incentives
4. market based mechanisms
5. active control:
   i. demand-side matching of unlocked flex by smart control
   ii. DSO safety-net: intrusive intervention as last resort before blackout



source: whitepaper Toekomstbestendige Flexibiliteit in het Energiesysteem (Stedin, feb 2025), based on measures described in the 'Actieagenda netcongestie laagspanningsnetten' (KGG)

Example of tariff incentives: TOU tariffs

- NL grid connection tariffs are currently capacity fixed: 1 x 35A or 3 x 25A for houses
- NL lacks behavioural incentives to avoid of inefficient energy usage during congestion peaks
- Introducing Time of Use (TOU) KWh tariffs will decrease the usage peaks with 3% - 12% for low voltage grid trafo's
- Alternative approaches for tariff incentives: time-of-use, power-peak and incident -based



source: Verkenning alternatief nettariefstelsel kleinverbruik (Berenschot, feb 2025)

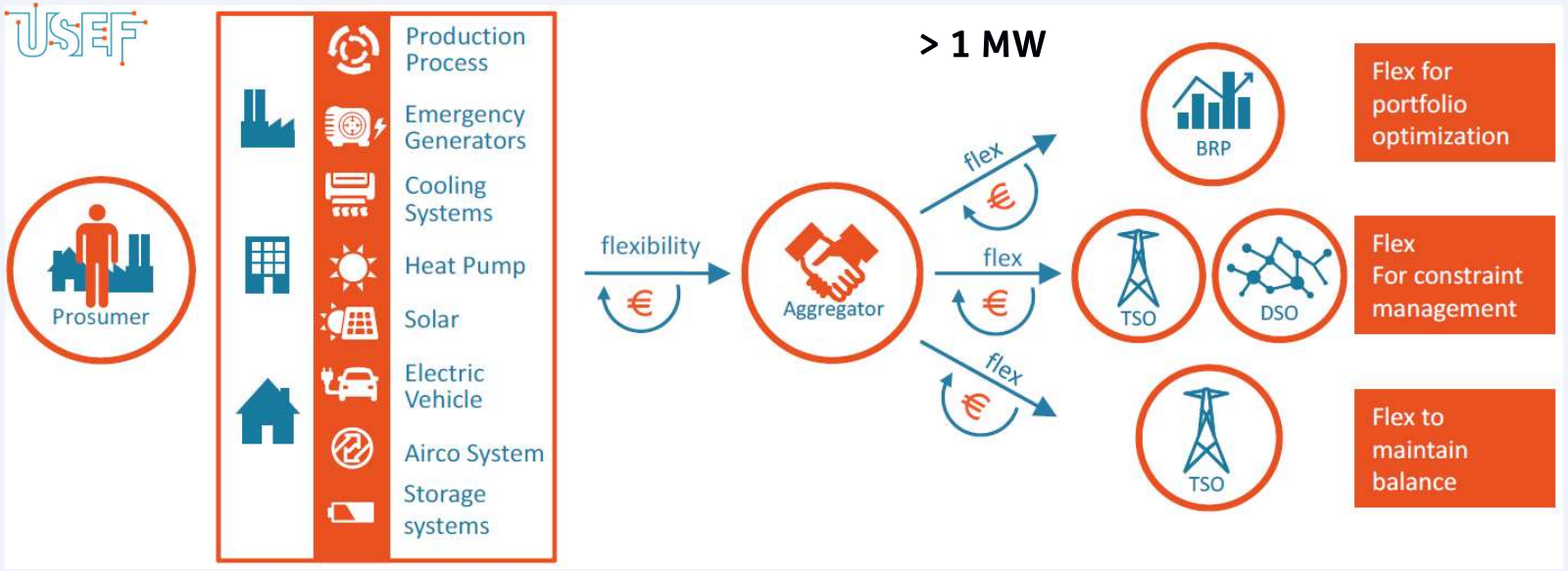
TOU kWh tariffs expected to replace capacity fixed grid connection tariffs by 2029 (indication by KGG)

Unlock & control energy flexibility

need for flex:

- Demand-side response required for business case CO_2-free energy
- Balancing national grid
- Congestion in HV & MV grids
- Congestion in LV grid
- Reduce grid reinforcement need
- Local balancing

unlocking of flex + smart control:



demand-side matching
smart control of flex-unlocking devices ..

trading & sharing
.. interaction with digital flex markets and/or local within energy communities and hubs

Current energy flexibility markets

Wholesale markets

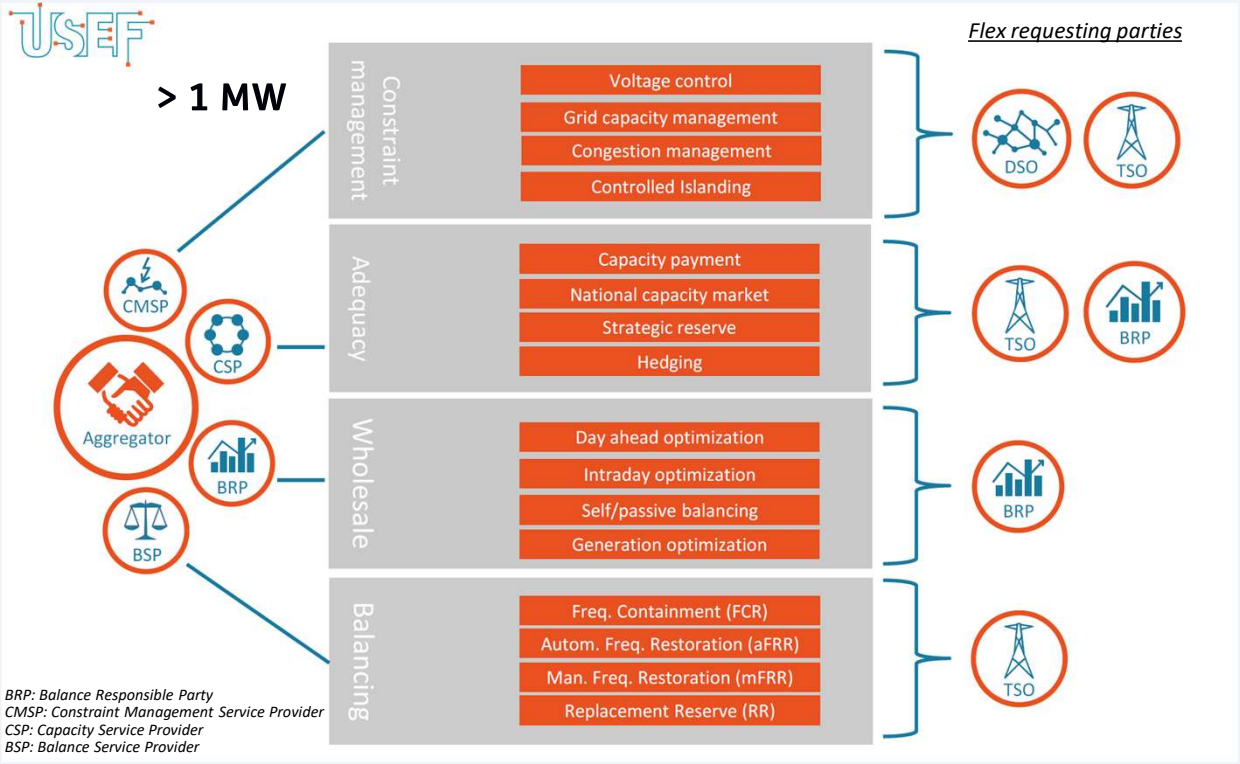
- **day-ahead**
  daily demand & response auction for hourly energy supply tariffs (for next day)
- **intraday** (> 1 MW)
  continuous "pay-as-bid" energy trade (for the same day)

Balancing markets (> 1MW)

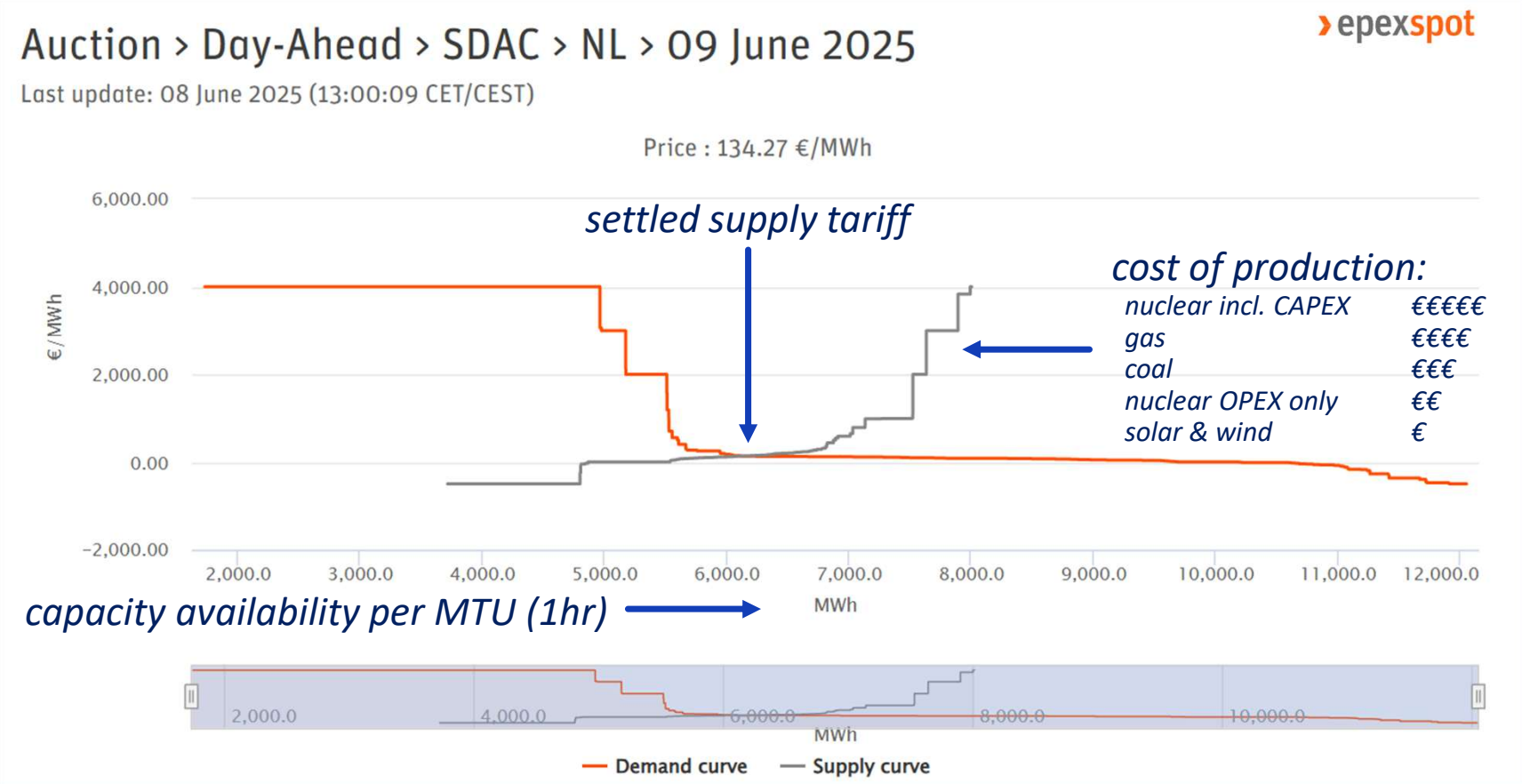
- **FCR** (Frequency Containment Reserve)
  automatically restore grid frequency deviations, within 4 sec
- **aFRR** (automatic Frequence Restoration Reserve)
  restore grid balance, within 30 sec, 20% / min
- **mFRR** (manual Frequency Restoration Reserve)
  contracted emergency capacity (e.g. in case of power plant failure)

Congestion management markets (> 1 MW)

- **GOPACS**
  capacity redispatch offering in/outside congestion zones
  grid operators select and match the (re)dispatch offers



Day-ahead: merit order determines the tariffs



SDAC Market Time Unit (MTU) for EU will change: 1 hr → 15 min per 1 Oct 2025

Demand-side matching

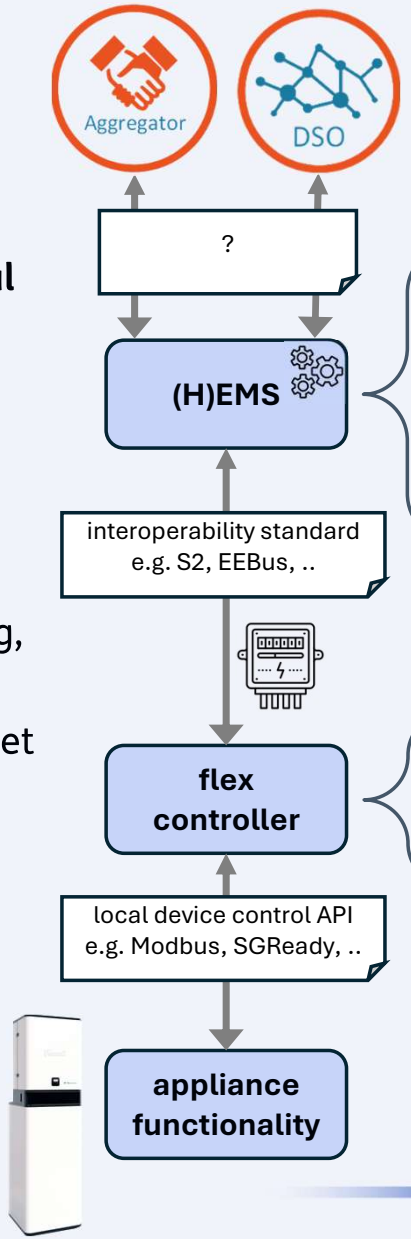
<u>Automatically</u> unlock flex from devices with flex potential

- open standard protocol to unlock and control smart appliances (behind the meter)

  protocols: S2 (EN 50491-12-2), PAS 1878/1879, EEBus (EN 50631), OpenADR, SGReady, Modbus, ..
- unlocked flexibility is controlled (optimized) by an EMS
- the EMS can use the flex for local demand-side matching, or trade the flex on energy markets
- (future) direct intervention possible via the DSO safety-net

Example smart appliances with flex potential, the 'big 4':

- (hybrid) heath pump & airco
- EV charger
- solar / PV inverter
- battery



- responsibility of aggregator, supplier, energy hub, local energy community, house owner, ...
- implementation of flexibility use cases

  (dynamic) tariffs, self-optimization, congestion mngt
- optimization strategy over controlled appliances
- typically deployed local or in the cloud

- unlocks flexibility options from smart appliance
- safeguards safety and performance constraints
- typically integrated in the device

Example: S2 open standard interoperable approach

8 generic energy flexibility capabilities ...

Power modulation

Buffer energy (e.g. power to heat)

Limit production / consumption

Store energy

Pause a task

Alternative profile same end result

Switch energy source

Shift in time

... are combined into 5 control types ...

Power Envelope Based Control
- Limit production / consumption

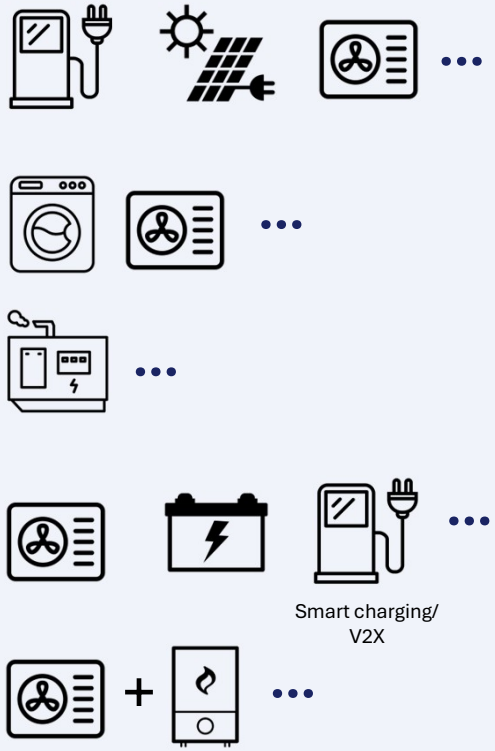
Power Profile Based Control
- Shift in time
- Alternative profile same end result
- Pause a task

Operation Mode Based Control
- Power modulation

Fill Rate Based Control
- Buffer energy (e.g. power to heat)
- Store energy
- Power modulation
- Switch energy source

Demand Driven Based Control
- Power modulation
- Switch energy source

... to manage flexibility of energy smart appliances



ENERGY SHARING & P2P TRADING

Now it is not possible in the NL to have more than one energy supplier per connection.

This blocks energy sharing and/or P2P trading of local generated renewable energy, both needed for realizing local energy communities fully supporting demand-side matching scenarios.

The EU commission mandated that:

- *'customers will get the right to sign multiple, long-term secure and dynamic pricing, contracts with different suppliers at the same time'*
- *'customers will be able to share their renewable energy with anyone, outside their suppliers'*

Example: what's needed to realize energy sharing and/or P2P trading

✓ physics fully supports local energy sharing ← electricity flow adheres to Ohm's law

1. local marketplace
2. local transaction registration + smart meter measurement
3. transaction settlement incl. 'local energy sharing' tax discount
   .. requires a reform of national energy tax policy and regulations

European Commission - Press release

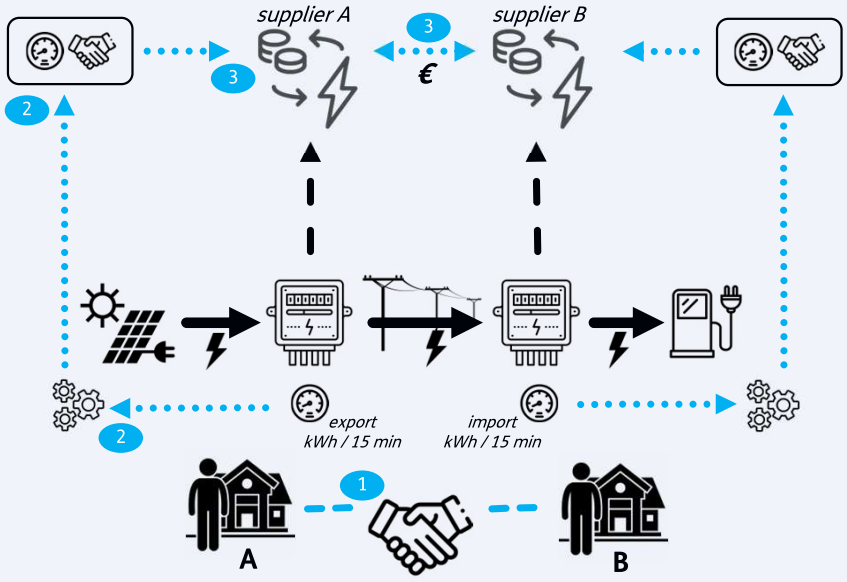
Commission proposes reform of the EU electricity market design to boost renewables, better protect consumers and enhance industrial competitiveness

Strasbourg, 14 March 2023

Today, the Commission has proposed to reform the EU's electricity market design to **accelerate a surge in renewables** and the **phase-out of gas**, **make consumer bills less dependent on volatile fossil fuel prices**, **better protect consumers** from future price spikes and potential market manipulation, and **make the EU's industry clean and more competitive.**

The EU has had an efficient, well-integrated electricity market for over twenty years, allowing consumers to reap the economic benefits of a **single energy market**, ensuring security of supply and stimulating the decarbonisation process. The energy crisis spurred by Russia's invasion of Ukraine has underlined the need to quickly adapt the electricity market to **better support the green transition** and offer energy consumers, both households and businesses, **widespread access to affordable renewable and non-fossil electricity**.

The proposed reform foresees revisions to several pieces of EU legislation – notably the Electricity Regulation, the Electricity Directive, and the REMIT Regulation. It introduces measures that **incentivise longer term contracts** with non-fossil power production and bring **more clean**



Wrap-up

Net congestion is one of the current consequences of the transition from fossil-based to renewable energy sources

Costly full grid reinforcement can partly be prevented by **unlocking flexibility**

Demand-side matching can improve consumption from local energy supply sources

Energy communities and hubs will in the future support both **energy sharing** and **P2P trading**, however we need regulatory and tax policy reforms first to secure the needed behavioral incentives


Thank you!
TNO innovation for life