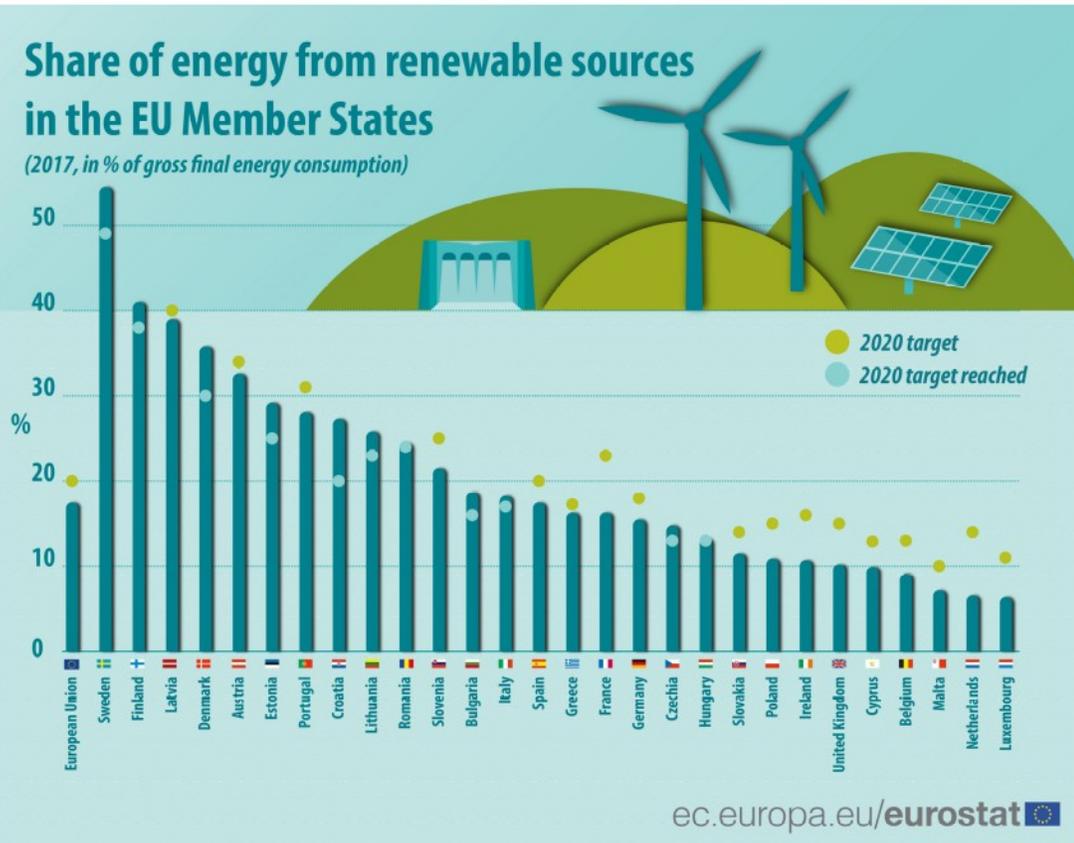


# Migrating from Natural Gas to Wind and Hydrogen in the Netherlands

Peter Palensky  
TU Delft

# “Klimaat-Akkoord 2019”

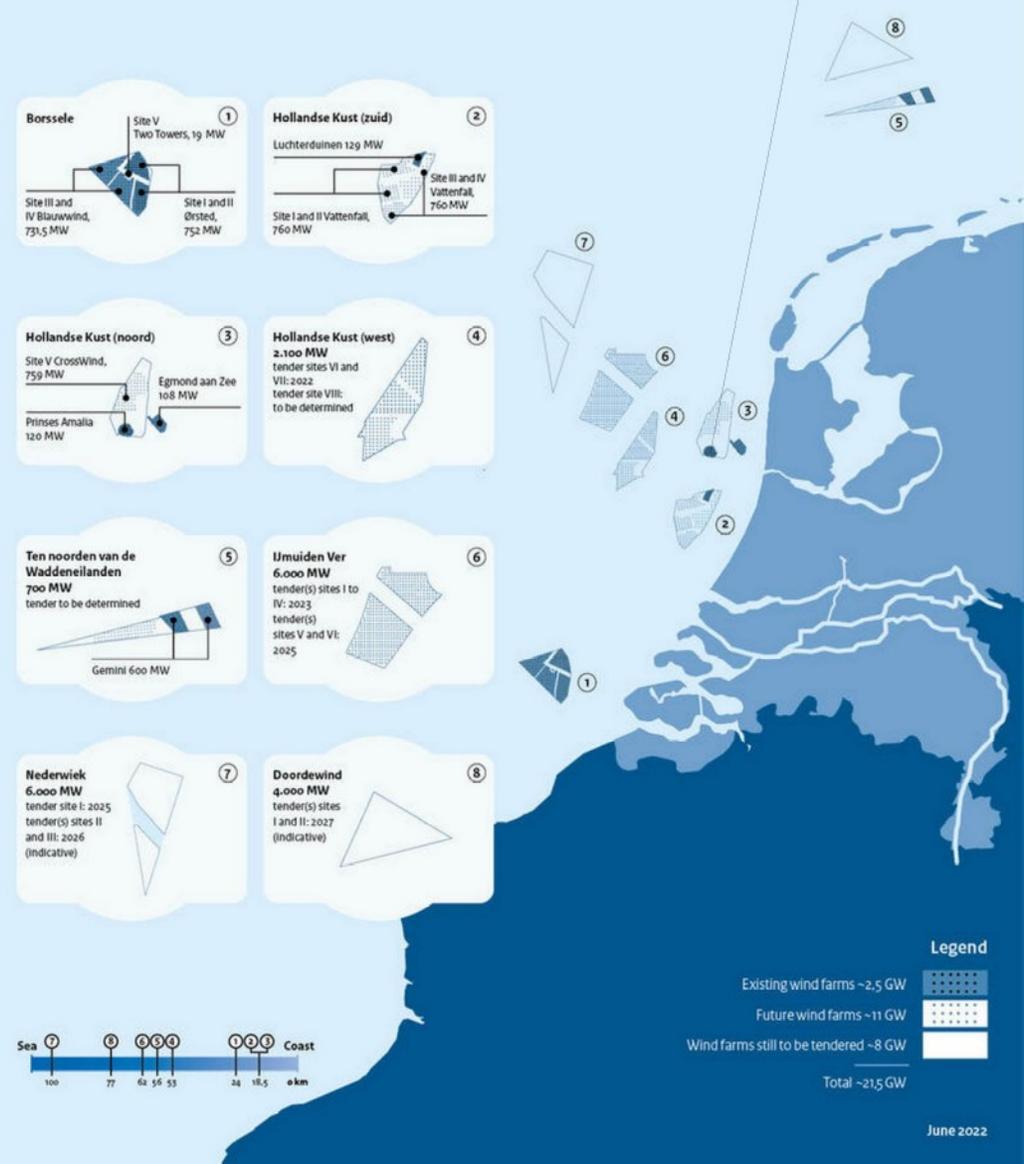
- 50% reduction of GHG by 2030
- ~100% clean 2050
- No gas heating 2050
  - private homes: 2030
- Heat pump prices vs. "cost neutral"?



# Wind @NL

- 9 GW, 2.5GW offshore
- New tenders
  - 21GW@2030
  - Integration
  - Floating solar
  - Ecological

## Offshore Wind Energy Roadmap



# “Target Grid”

- TenneT 2045
- Wind
- Energy Hubs
- DC Corridors
- MT-HVDC



# Energyhub(s) in North Sea

- Abundance of wind
- Cable: 1GW
- H2-Pipe: 15GW
- Airfield, harbor, hotel, industry, etc.
- Grid integration?
- MT-HVDC with MMC?
- Interoperability?



MT-HVDC: Multi-Terminal High-Voltage DC  
MMC: Modular Multilevel Converter

# A hydrogen hub in the North Netherlands

A solution for huge fluctuations between supply and demand



Wind farms

From 2019:  
cable for surplus  
Danish wind  
energy

Green power  
from Germany

Plus:

- Retrofit gas power station to H<sub>2</sub>
- Norwegian gas to H<sub>2</sub> (CO<sub>2</sub> back)
- Truck H<sub>2</sub> filling station
- Energy-wise great, but...

Solar farms

From electricity...

...to hydrogen...

Electrolysis: separating water into hydrogen and oxygen

...to storage...

Underground gas storage Zuidwending  
Hydrogen storage in salt caverns

...to consumers

Methanation:  
CO<sub>2</sub> from the air reacts with hydrogen to form syngas  
which can be injected into the natural gas network

Blending H<sub>2</sub> into  
the natural gas network

Conversion into  
electricity

Hydrogen  
fueling stations

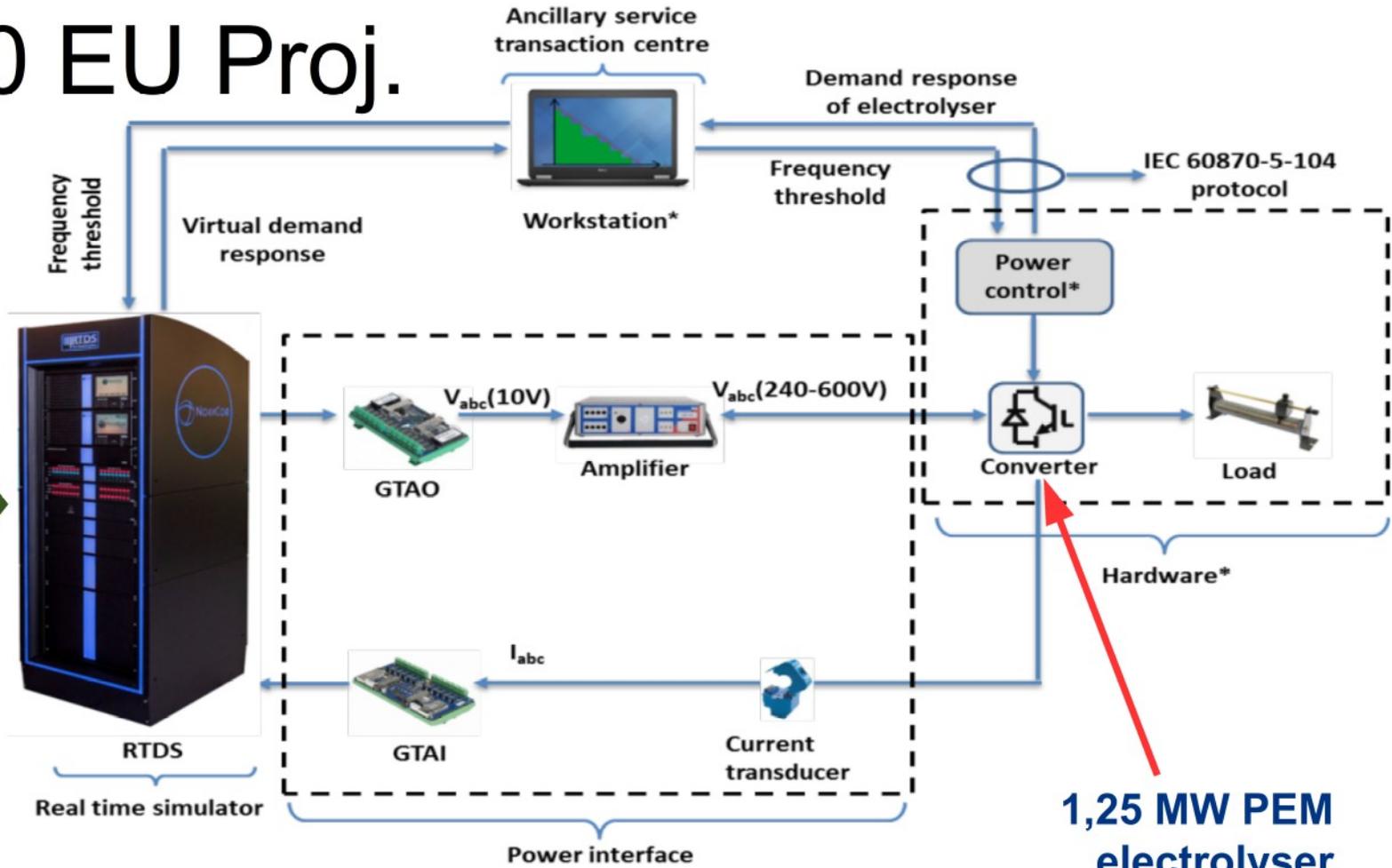
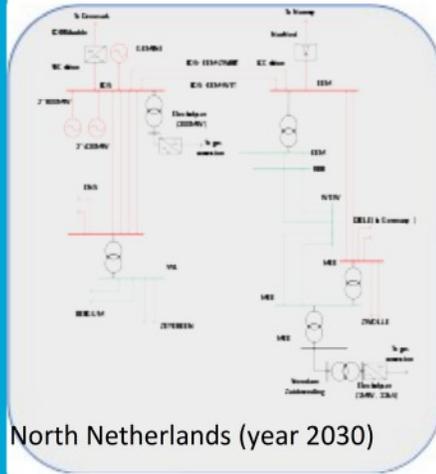
Houses

Transport

Industry

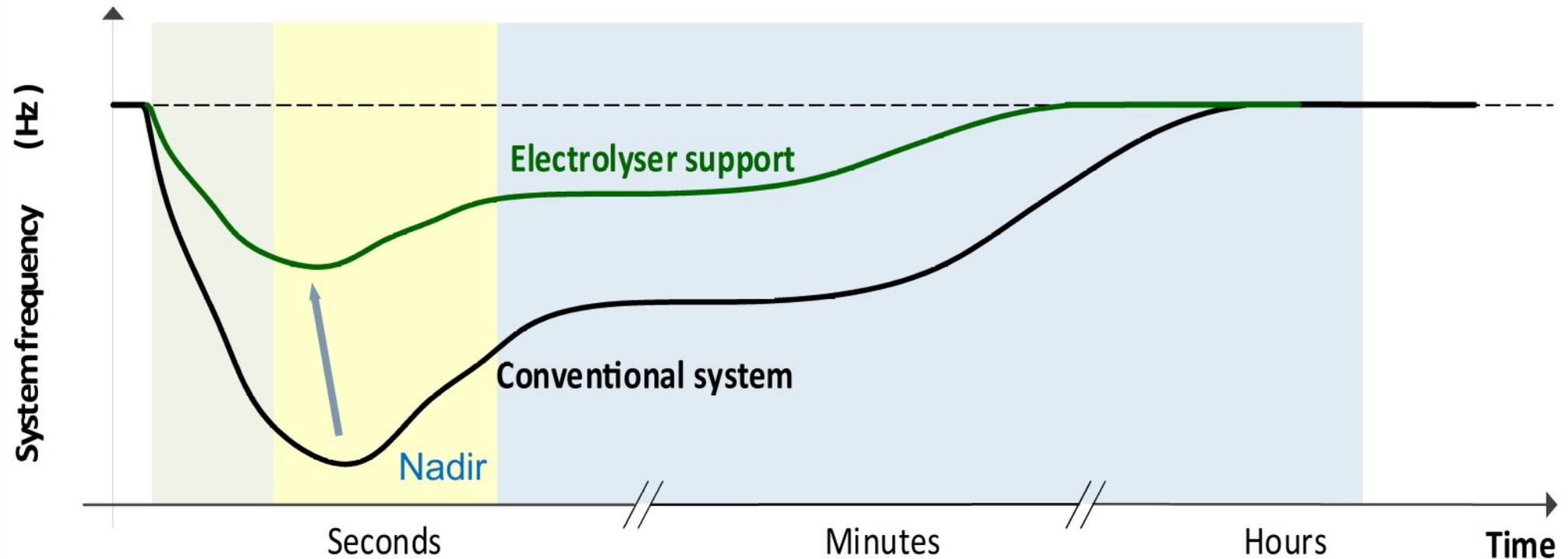
# TSO 2020 EU Proj.

EMT system model



# H<sub>2</sub>: Troublemakershooter

- Fast active power regulation

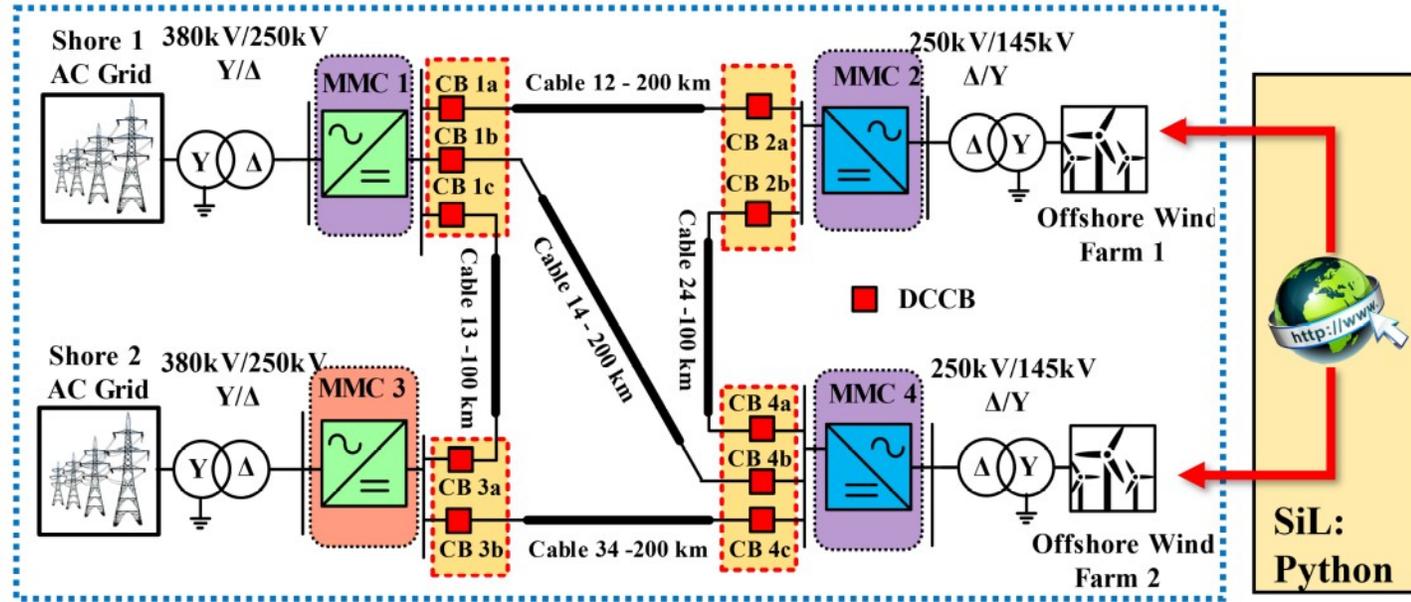


# MT-HVDC: HW/SW in the loop

Control System



Power System



Hardware



# Lessons learned

- Integration unlocked by digital tech
- New components (DC circuit breakers, controls, etc.)
- Interoperability? → Replicas
- Multi-stakeholder setting: Models help
- Political support is key

