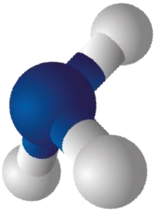
Proton Ventures

Decentralised Ammonia Production

In the Netherlands;

the solution for storing

sustainable energy



Presentation dd 21-9-2016

www.protonventures.com

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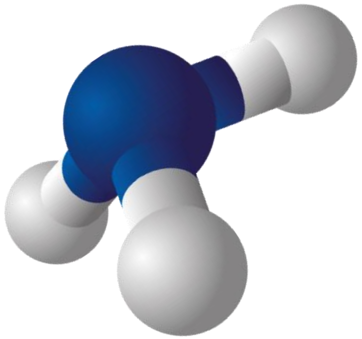
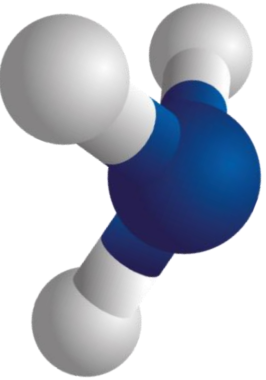
Our Vision



- **Our vision is to develop and implement**
  - **sustainable,**
  - **decentralized and**
  - **small-scale ammonia production plants and/or energy storage systems , stored as anhydrous ammonia**



for various applications such as

- **fuel storage applications,**
- **chemicals and/or,**
- **fertilizers**

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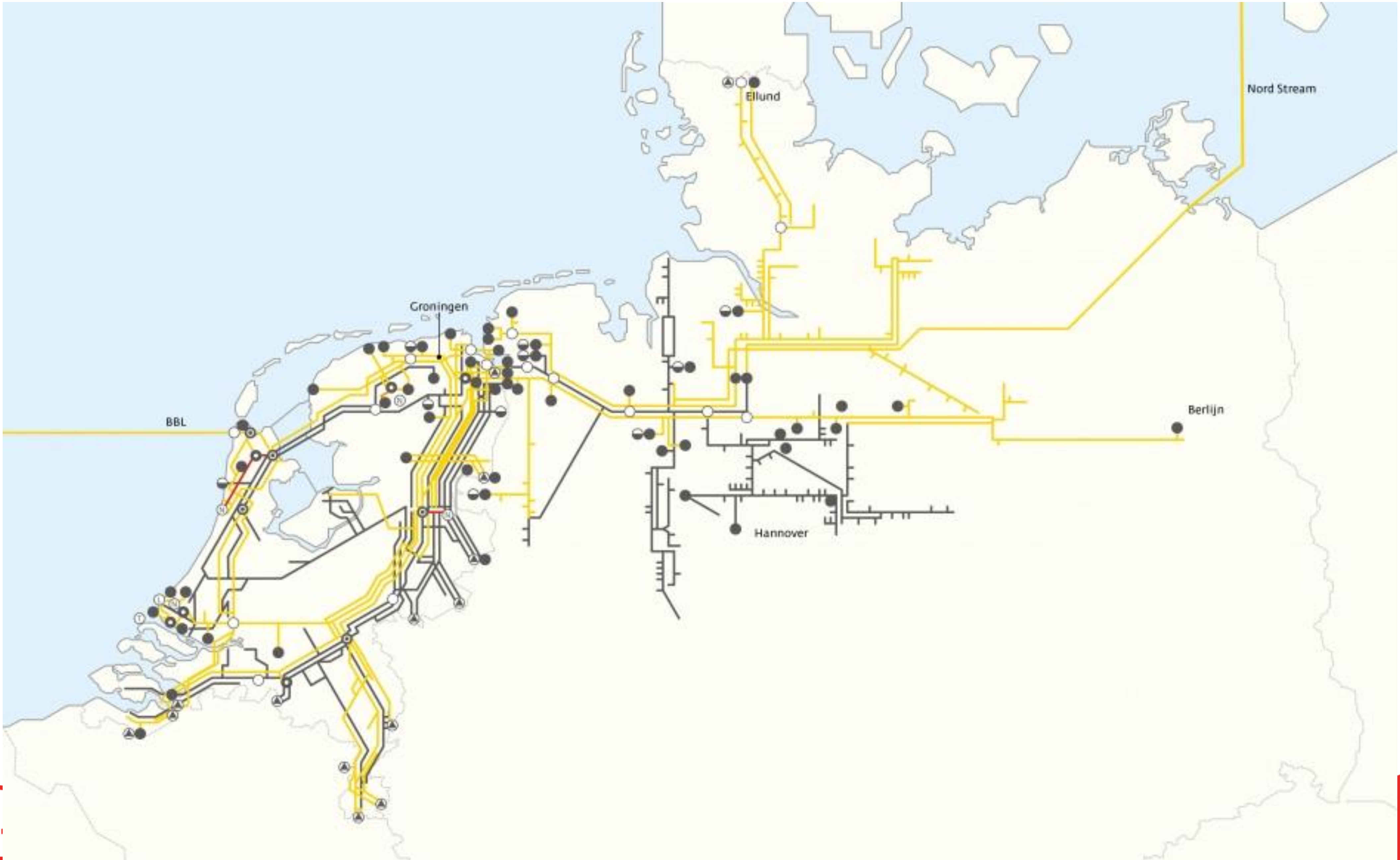
Ellund
Nord Stream
Groningen
BBL
Berlijn
Hannover

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Just a case study

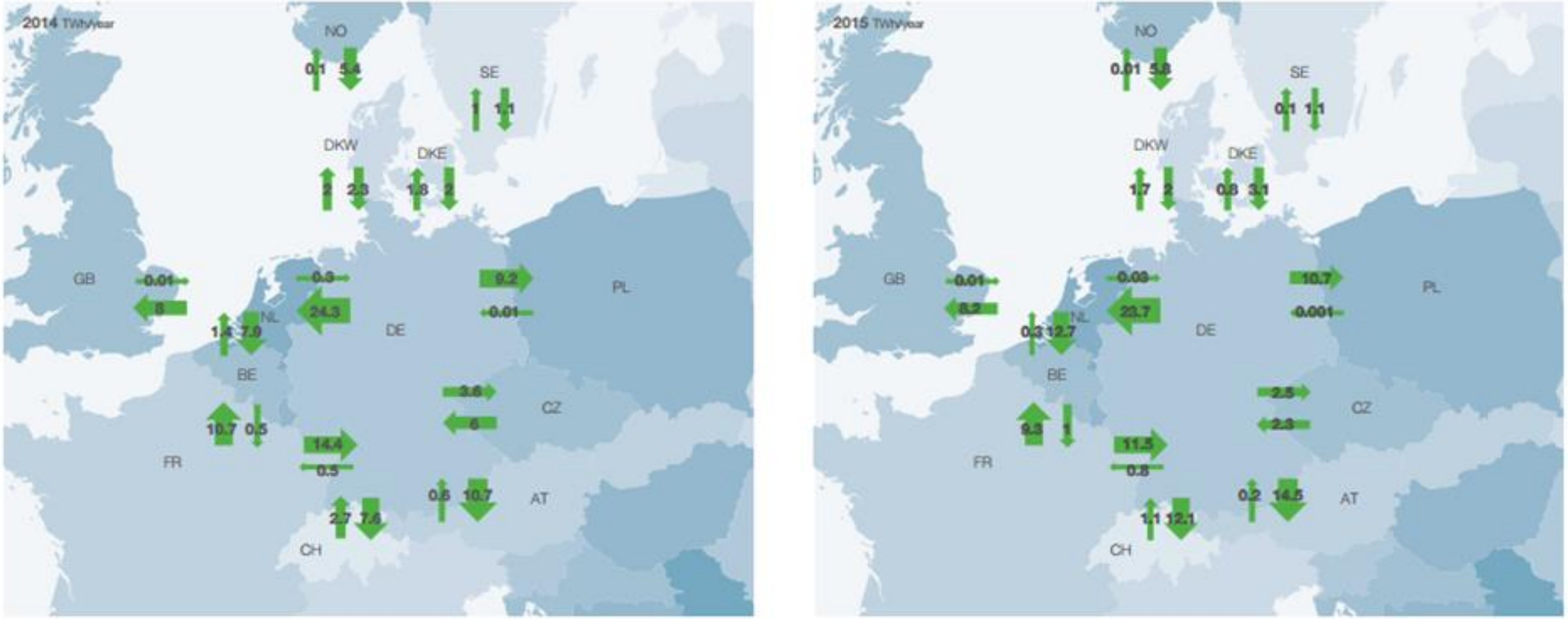

Figure 28: Annual total of physical cross-border flows in CWE region and at the German borders in TWh. Source: TenneT, ENTSO-E, Swissgrid

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GEEN KOLEN
MAAR
WINDMOLEN

Nuon-4-ammonia

- https://www.youtube.com/watch?v=VRUzakQkvwM

- Superbatterij-Eemshaven.mp4

The Dutch Grid

NH3_Storage 1

NH3_Storage 2

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“The case study”’
sponsored by RVO and partners

- Extended Literature Search
- Out of box thinking
- Market studies on Power and chemicals under study
- Recent problems and CO2 emission targets
- Stake holder discussions
- Actual project ideas

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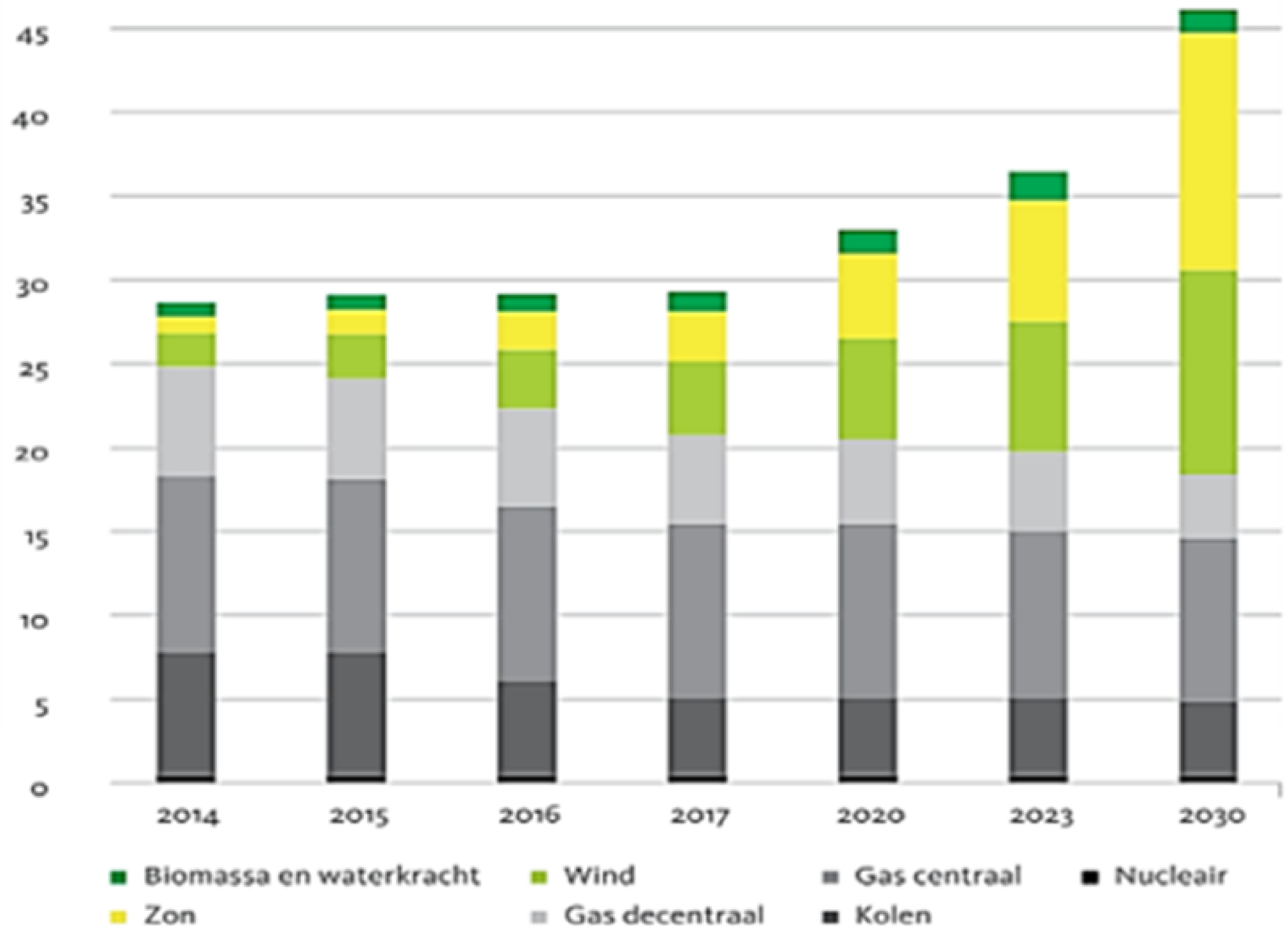
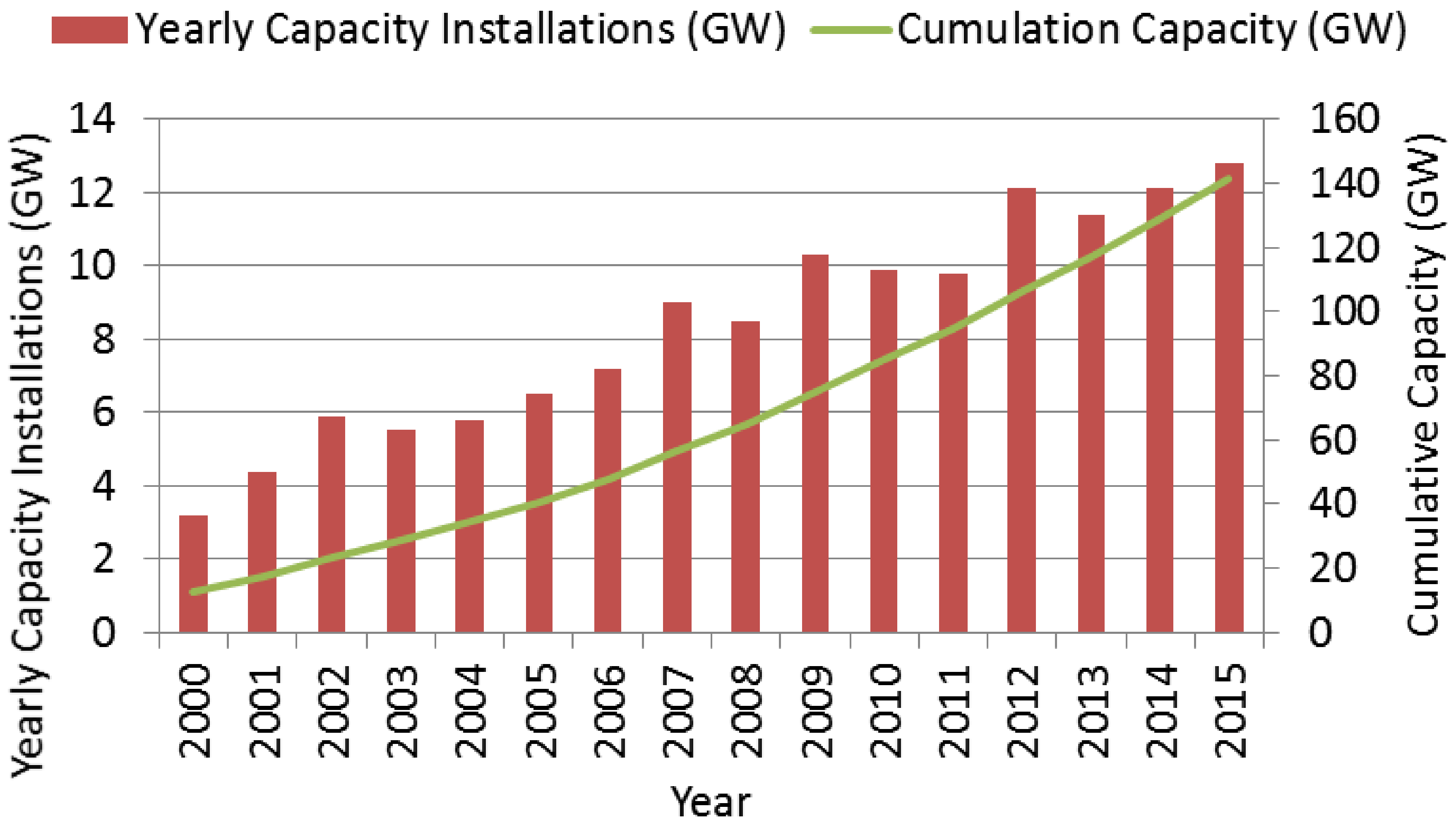
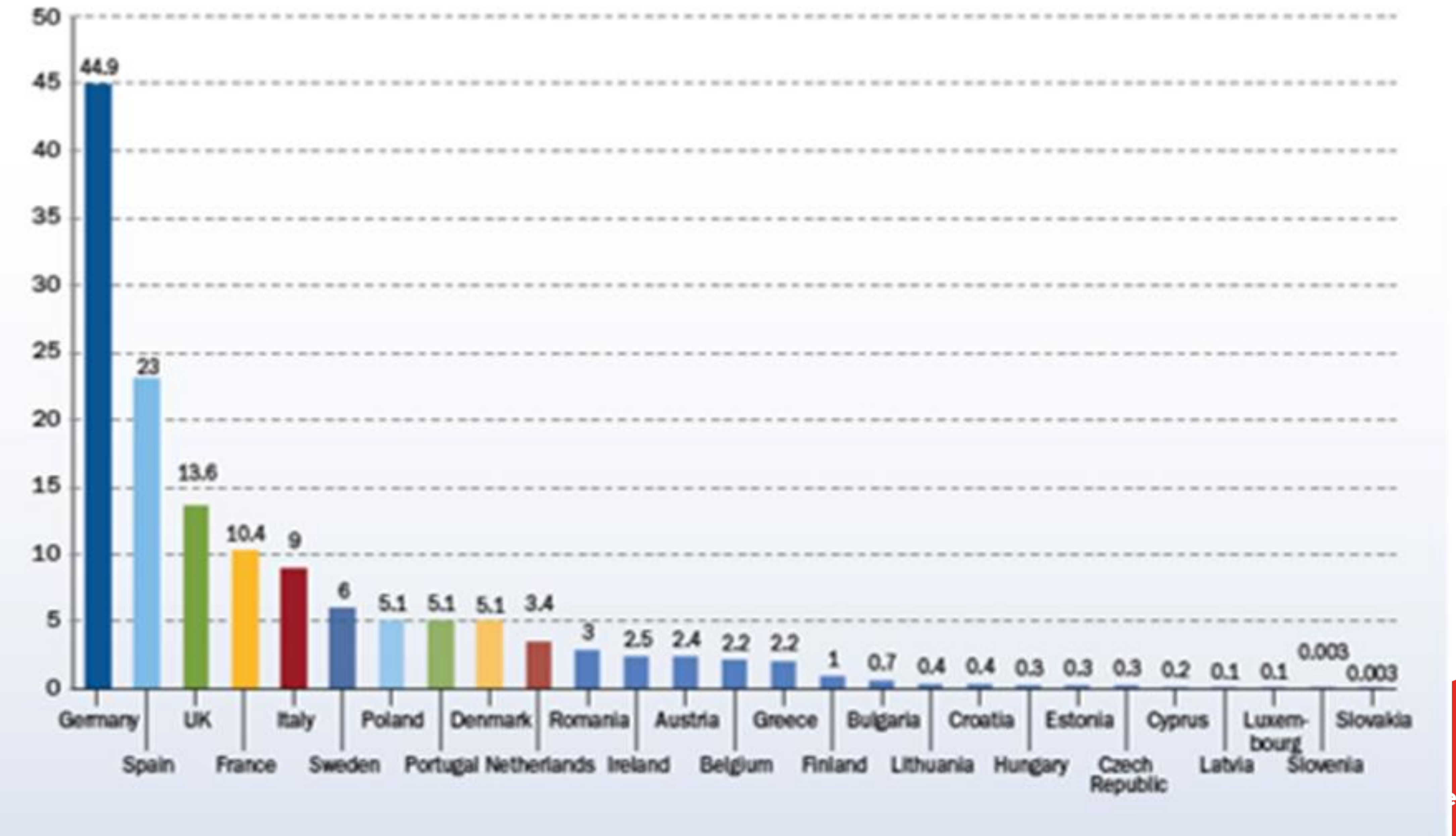
Capacity development in the Netherlands (GW) 2014-2030. Source: (Triple 2015)



Growth of wind power in the European Union



EU member state market shares for total installed capacity (GW). Total 141.6 GW. Source: (EWEA 2016)



European cross-border flows. (Source: (TENNET 2016))

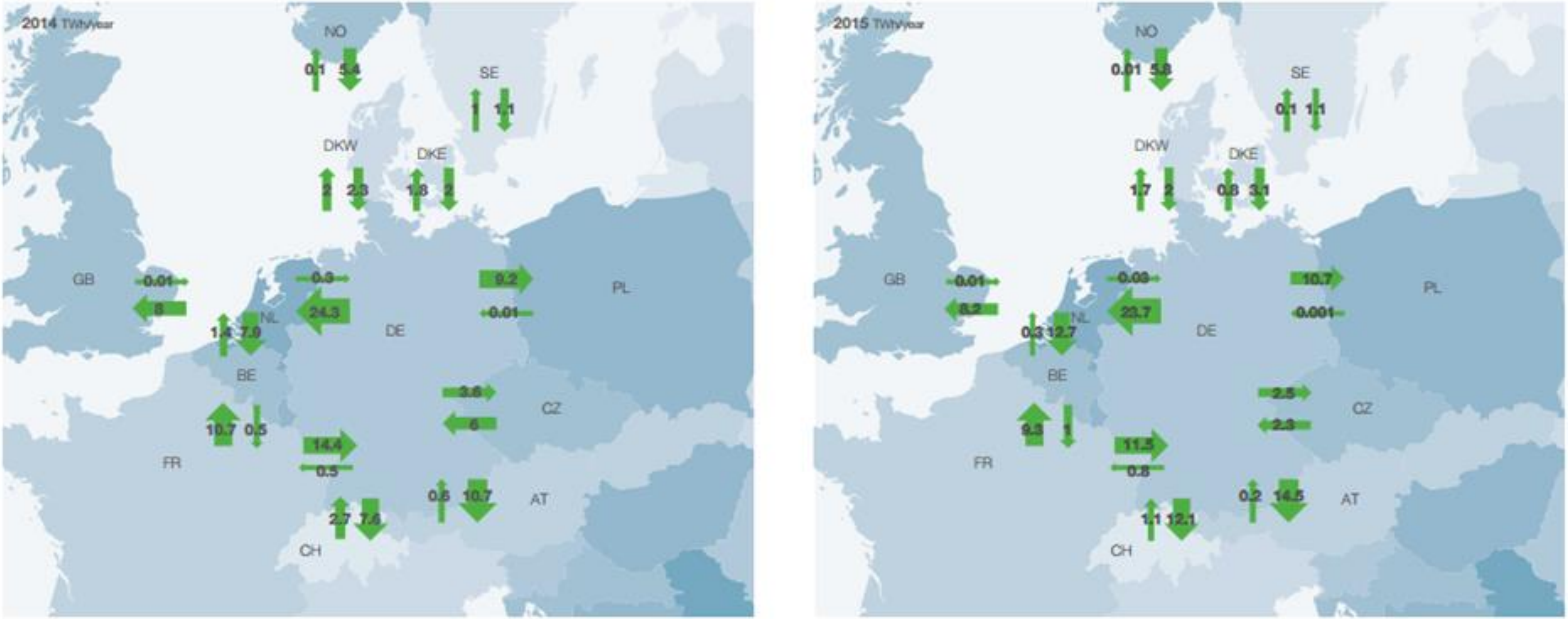
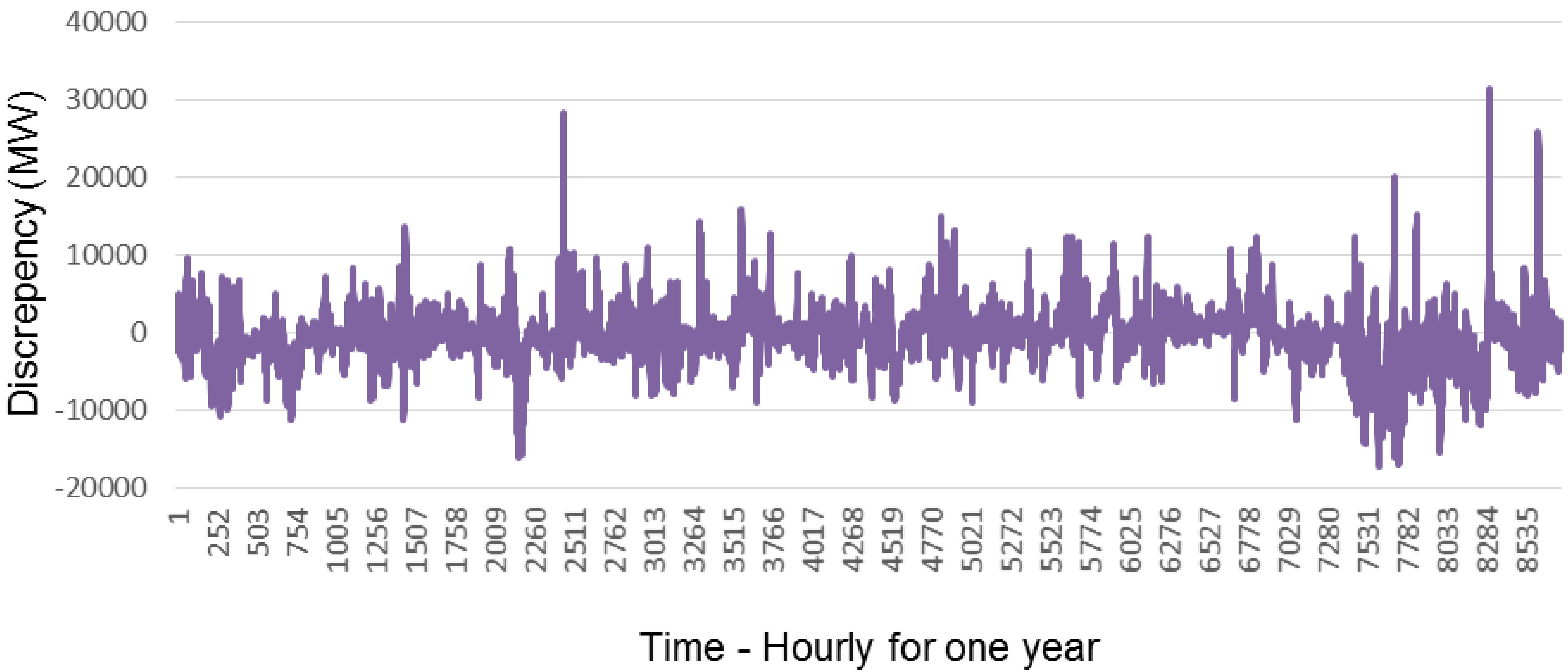


Figure 28: Annual total of physical cross-border flows in CWE region and at the German borders in TWh. Source: TenneT, ENTSO-E, Swissgrid

Discrepancy (Actual – Forecast wind power) per hour in Germany



Hourly discrepancy (Actual – Forecast wind power) in Germany

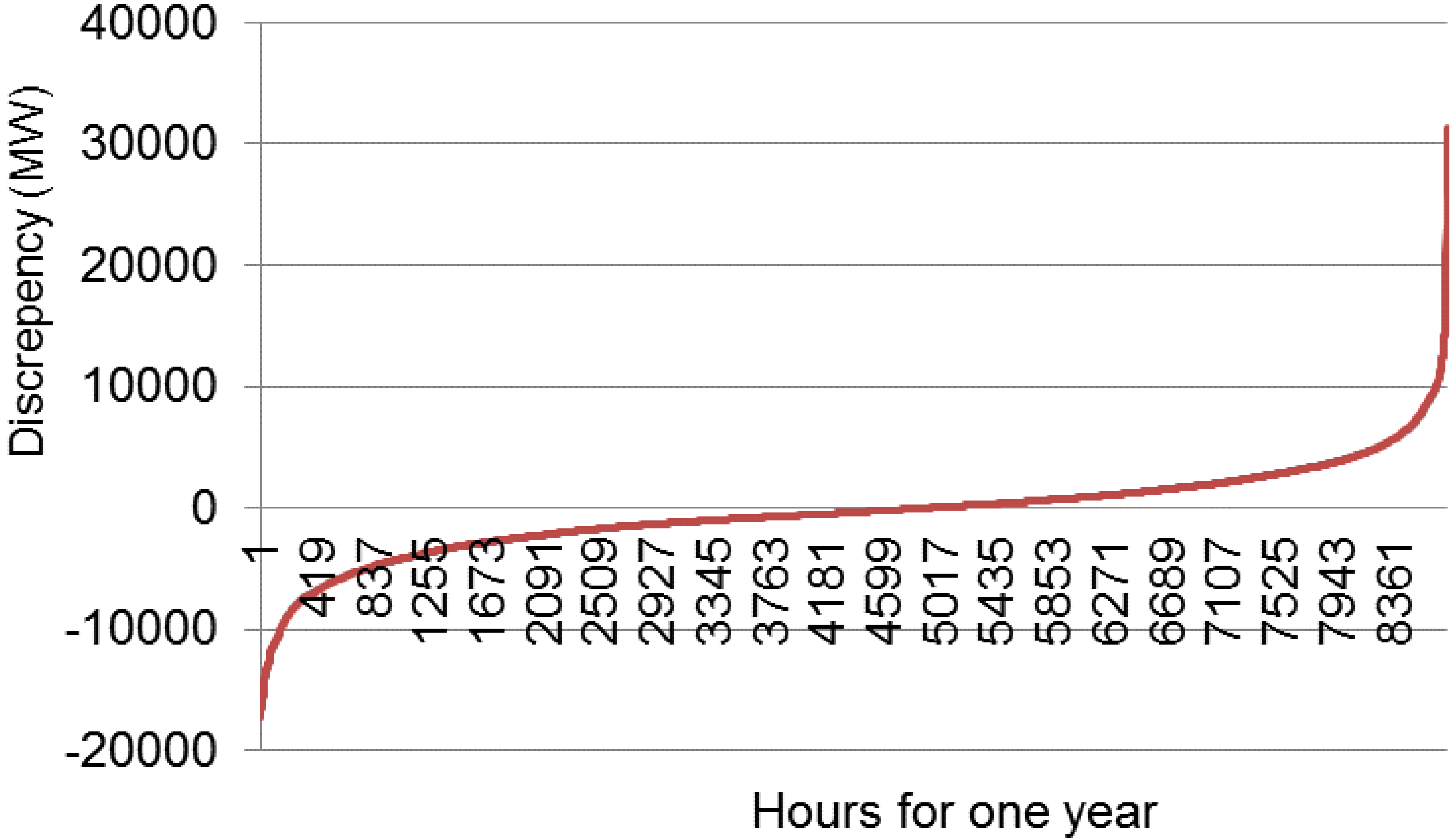
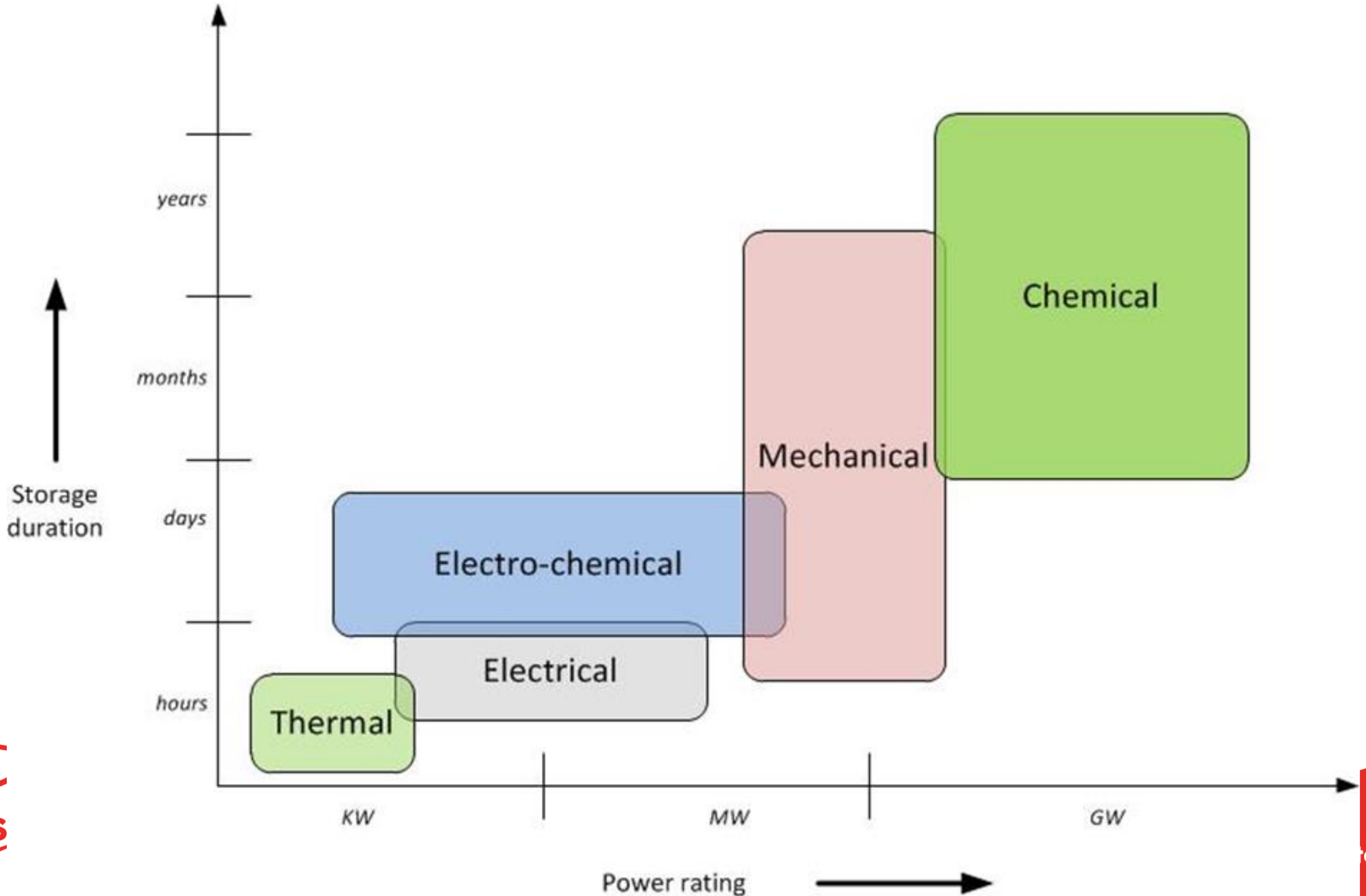


Table 4.1: Energy storage technologies

Storage type		Power rating	Suitable storage duration	Response time	Technical lifetime	Technological maturity
Mechanical	**Pumped Hydro**	100 MW to GW's	hours to years	sec-min	25+ years	Commercial
	Compressed Air	10-100 MW's	hours	sec-min	25+ years	Commercial
	Flywheel	1 MW	hours	sec-min	20 years	Commercial
Electrical	**Capacitors**	<100 kW	<1 hour	sec	25+ years	Partially commercial
	Superconductor magnet	10 kW-1 MW	<1 hour	sec	25+ years	Partially commercial
Electro-chem	**Battery (various types)**	<50 MW	min-hours	sec	5-10 years	Commercial
Chemical	**Hydrogen**	kW-GW	hours to years	sec-min	20 years	Development
	Ammonia	kW-GW	hours to years	sec-min	20 years	Development
Thermal	**Sensible/latent heat**	10-100 kW's	hours	sec-min	5-10 years	Partially commercial

Overview of energy storage technologies



Production, transport and storage costs for ammonia and hydrogen

	Hydrogen (€/kg H_2)	Ammonia (€/kg H_2)
Production	2.70	3.40
Pipeline transport	1.69	0.17
Storage		
1 day	0.71	0.03
15 day	1.78	0.05
182 day	13.48	0.49

Roadmap CO_2 Reduction NL – Nuon View

First step until 2030: ***Current technologies***

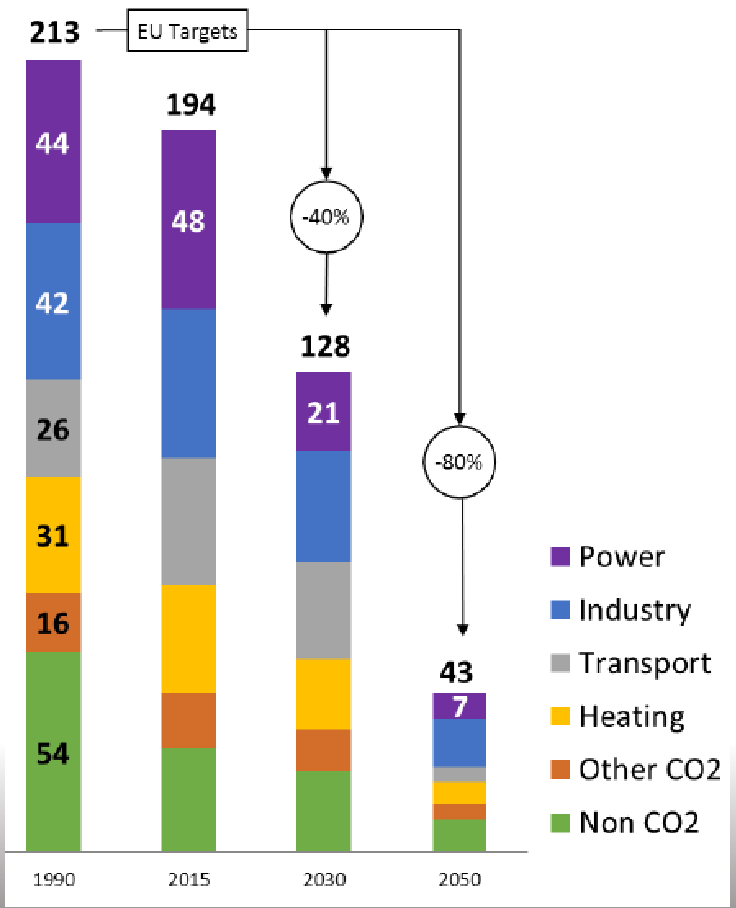
Power CO_2 emissions reduction towards ~21 Mton in 2030,
Total demand: ~120 TWh
Average CO_2 emission: ~175 kg/MWh

- Primarily wind/solar new built, 50% of demand
- Phasing out coal or decrease emissions to level of gas
- Gas: ~18 Mton emissions for ~45 TWh of power
- Other emissions waste/industry related
- Demonstration of (storage) technologies needed >2030

Second step after 2030: ***Tech to be developed***

Power CO_2 emissions reduction towards ~7 Mton in 2050
Total demand 150..200 TWh due to electrification.
Average CO_2 emissions: <50 kg/MWh

- Remaining gas CCGT (20 TWh / 7 Mton emissions)
- Wind / solar up to 60% of demand
- new built power production and storage that needs to be (a) flexible and (b) zero emission (~50 TWh)
- Large scale electrification of transport, industry, heating



Actual Plan in phases

- Production of ammonia in decentralised places
  - North Netherlands, in combi with H2 byproduct/ Electrolysers/Solar/wind
- NH3 storage 1
- Development of 400 ktpa ammonia convertor based on sustainable energy
  - Pricing realistic compared to peak power (@sustainable cheap NH3)
  - Economic at price levels of Peak power (max 5 times bottom price power)
  - Proven technology (Haber Bosch initial, later Battolyser/SSAS etc)
  - To avoiding grid problems (exactly at main grid)
  - Logistical problems solved (at shore)
  - Power production solved (guarantees by Power plant builders)
  - Accepted by stakeholders

Actual Ideas

- NH3 storage 2
- **Tidal Energy** based at no grid/low voltage grid
  - New infrastructure cheaper than cables (CAPEX discussion)
  - Logistics solved (short distances /conversion to urea)
  - Acceptable by Dutch laws (especially storage at tourist attraction)
  - Acceptable by Permitting conditions
  - Pricing of such ammonia/Power

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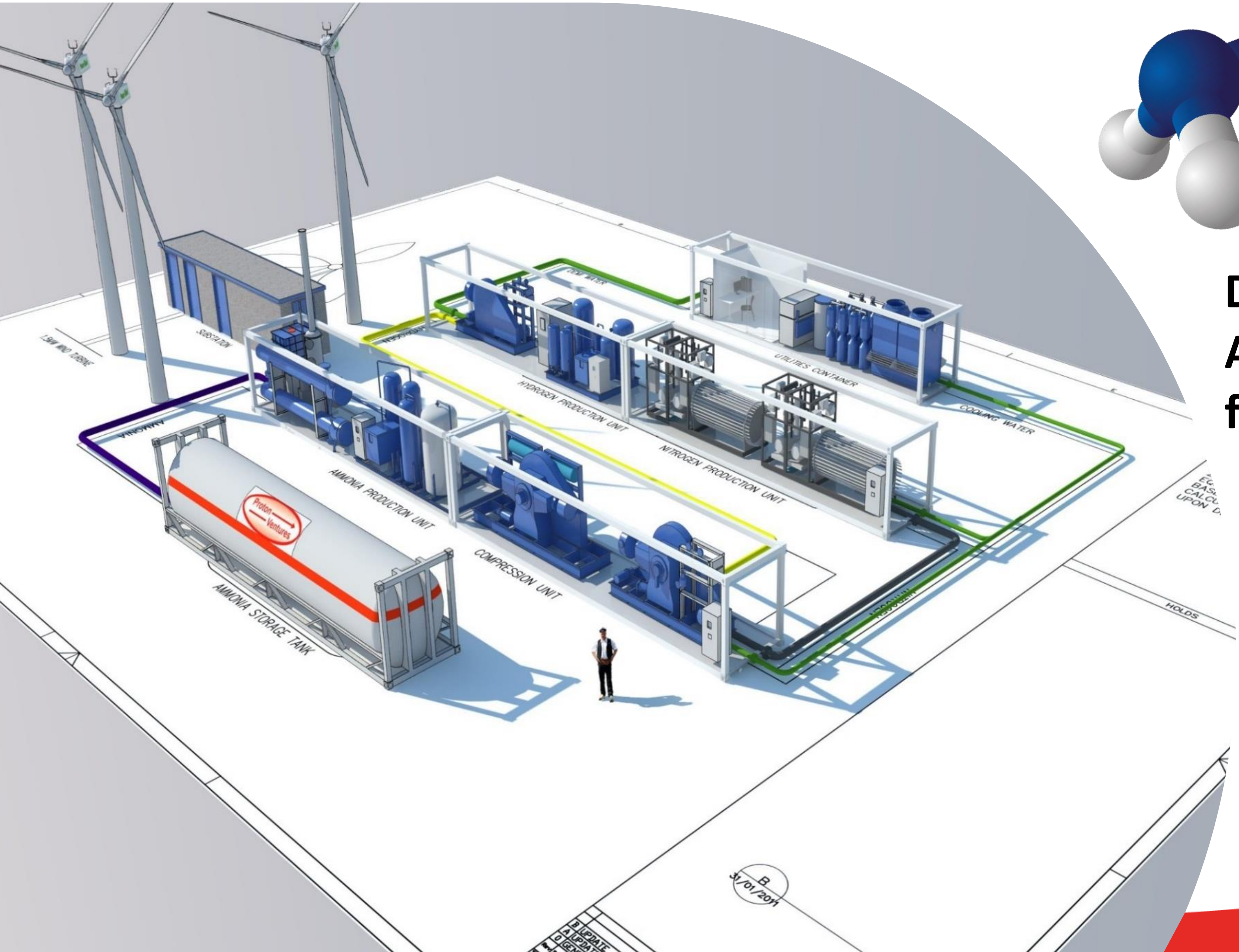
Ongoing projects

- Power/to/ammonia: Rethinking the role of ammonia/from a value added product to a flexible energy carrier
- Decentralized production of ammonia
- Power2Ammonia

  Value Chains and business cases in

  industrial and rural circumstances
- Gas2ammonia
  - Biogas, flared gas, waste gases

Proton's power - to - ammonia plant



Decentralized production of Ammonia for usage as a fuel, fertilizer or de-nox

Conclusions

- Small scale production of NH3 to solve CO2-emissions is “best solution”
- Can be economical at levels of app 300 Euro/t NH3
- Is proven technology for
  - Gas2ammonia/biogas2ammonia/Power2/ammonia
- NH3 conversion to Power expected to be “proven” for mix of 25% NH3 in Nat gas, to incresse to 40% target
- If 40% it seems solving the problems till 2030.
- Further improvements on technology always interesting/but mainly on H2 costs.

Thus:

- **Decentralised Power2ammonia is the only solution in NL and maybe many other countries/areas.**

Proton Ventures

Karel Doormanweg 5

Schiedam 3115 JD

The Netherlands

Telefoon: +31-10-4267275
Fax: +31-10-2730879
E-Mail: info@protonventures.com

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Thank you

Questions?