On the perspective of a hydrogen economy

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Fueling the future with renewable gases

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Greening so far

- **In 2016, renewable sources contributed 29.6% to the total EU-28 gross electricity consumption (Eurostat, 2018)**
  - Hydro power (36.9% of total renewable generation)
  - Wind (31.8%)
  - Solar (11.6%)
  - The remaining 19.7% is mainly produced by biomass.

- **Based on 2030 scenario analysis H2020 STORE&GO project (2017):**
  - Greening of annual 400-450 bcm EU natural gas limited so far to 4%, almost fully based on biomass digesters in EU
    Only 11% of it enters grid as biomethane (459 biogas upgrading plants in EU)

- **So, given that the gas part represents probably the greener part of molecules, the difference in the speed of greening between the electron and molecule part of the EU energy system is striking.**

Perspectives on greening

- **EU Energy Roadmap 2050, greening electrons:**
  - in 2030: 57–65 %
  - In 2050: 96–99%

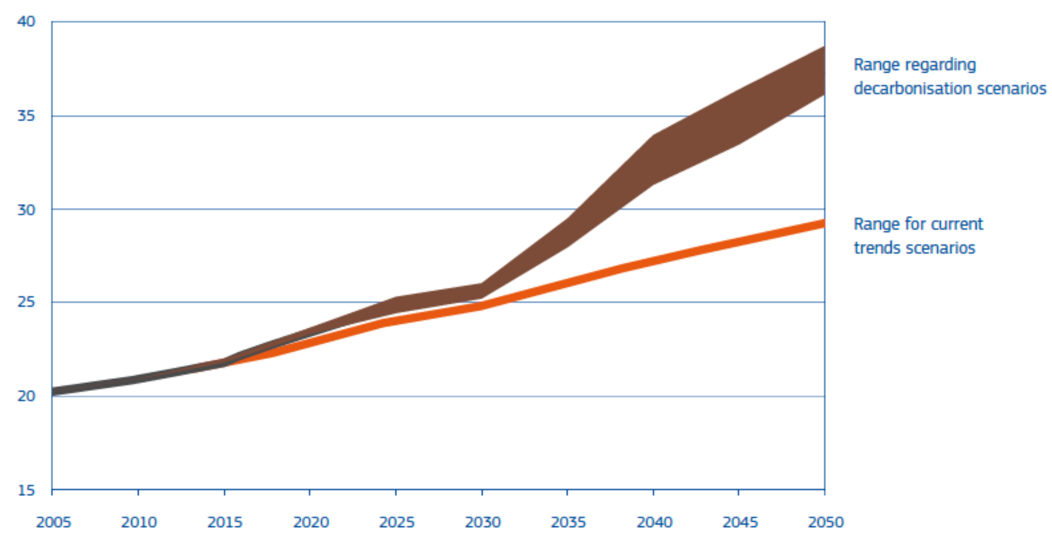
- **STORE&GO report on greening of gas:**
  - Perspective on additional physical greening limited (positive digestion, gasification and power-to-gas scenario: towards 13-14% at most in 2030)
  - Biogas and biomethane will then still dominate and can reach a level of some 10%.
  - By then, role of gasification and power-to-gas still limited due to length of technology cycle; on the longer term power-to-gas seems the only viable option to create substantial volumes of ‘green’ energy molecules (unless one would like to massively resort to certificate-based trading)

- **So, given the current policy bias, the key EU challenge seems to be to speed up ‘greening’ of energy molecules via power-to-gas technologies**

Is ‘all-electric’ trend likely?

- **Current ratio: about 20/80**
- **Future ratio: uncertain, but possibly 40/60**
- **Not unlikely: after energy transition, energy system will still be dominated by molecules, which are**
  - Cheaper to transport (10-20x)
  - Cheaper to store
  - Easier to implement
  - By proven and accepted technologies

Graph 2: Share of electricity in current trend and decarbonisation scenarios (% of final energy demand)

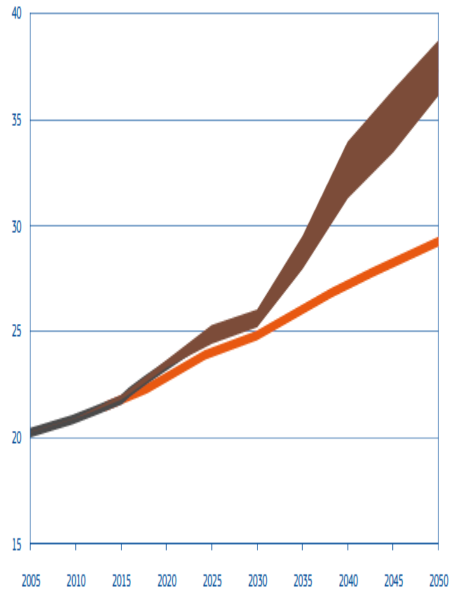


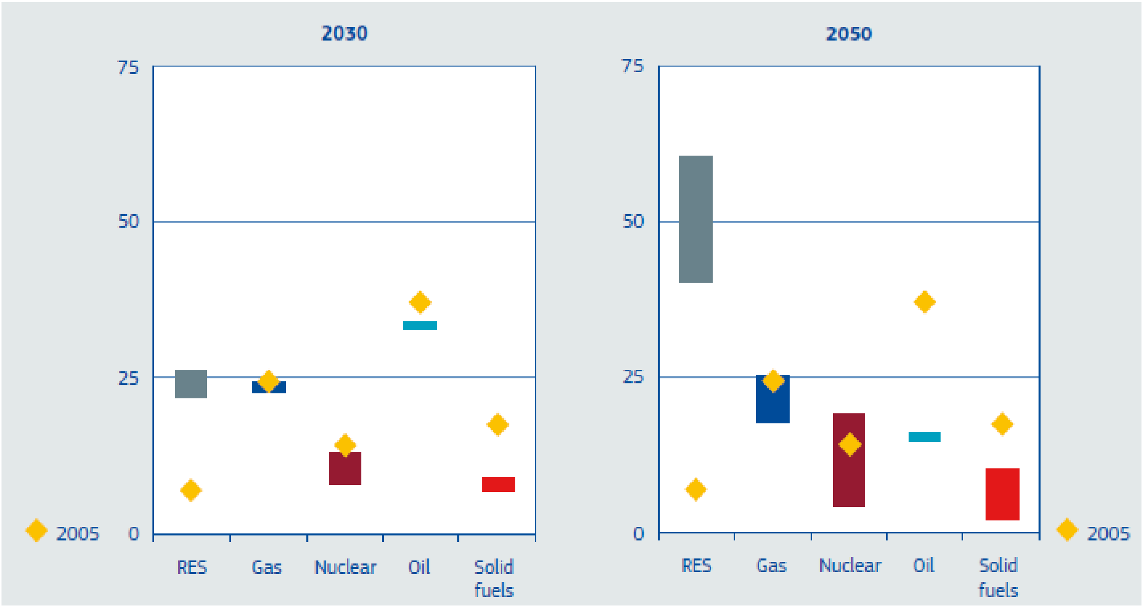
A future mismatch between green electrons and molecules?

- **EU Uptake E/M**
  - 2016: 23/77
  - 2030: 25/75
  - 2050: 40/60

EU Supply E/M

- 2016: 23/77
- 2030: 35/65
- 2050: 60/40





So, the EU supply/demand mismatch between electrons and molecules may create a formidable power-to-gas challenge (or import need) to get the energy molecules green in time.

Some projections on the future uptake of gases in the EU

- **EU28 (2016) gas uptake about 460 bcm (380 Mtoe), or some 23% of primary energy uptake**
- **EU28 reference scenario**
  - 2030: 440 bcm (24%) overall target 40% CO_2 reduction; 27% renewables
  - 2050: 450 bcm (25%) overall target 80-95% CO_2 reduction
- **Eurogas**
  - 2050: 460 bcm, of which 70% renewable
- **Own TD estimate based on EU28 energy balance data**
  - 2050: 450-455 bcm

- So, while overall energy uptake will slightly level off from about 1800 Mtoe to 1700 Mtoe by 2030 and thereafter (EU reference scenario; towards 1200 Mtoe in 'aggressive policy' scenario of EU Energy Roadmap 2050), the share of gas remains roughly the same

On the EU need for power-to-gas

- Assume the current uptake of gases (some 450 bcm/y) will remain about the same by 2050 (EU Reference Scenario)
- Assume (Eurogas) that by that time some ¾ of that will have to be green, or 350 bcm/y
- How can that be achieved?

How to green 350 bcm gas?
A guesstimate

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- The role of biomass will remain limited to some 75 bcm max.
- The role of CCS/CCU will remain limited, if only offshore empty gas fields can be used: some 75 bcm max.
- The scope for ‘green’ imported gases may remain limited to some 75 bcm max. (?)
- The remainder, or some 125 bcm will need to be provided by EU-wide power-to-gas. What would this mean for North Sea energy?

The need for power-to-gas

- The current EU wind capacity onshore + offshore is about 170 GW
- In order to generate some 125 bcm green hydrogen, all this capacity would be needed
- The projected extension of offshore wind capacity towards 2050 is also about 170 GW
- So, it would seem logical that a (substantial) part of the North Sea offshore wind power production will need to be converted into hydrogen in order to meet the demand for green molecules

How to calculate cost price of offshore hydrogen production?

- Pitfall 1: not taking into account the complete value chain (i.e. including transport and storage)
- Pitfall 2: not taking into account externalities (i.e. security of supply, environmental impact, non-internalised costs, public acceptance)

Power-to-gas cost price data

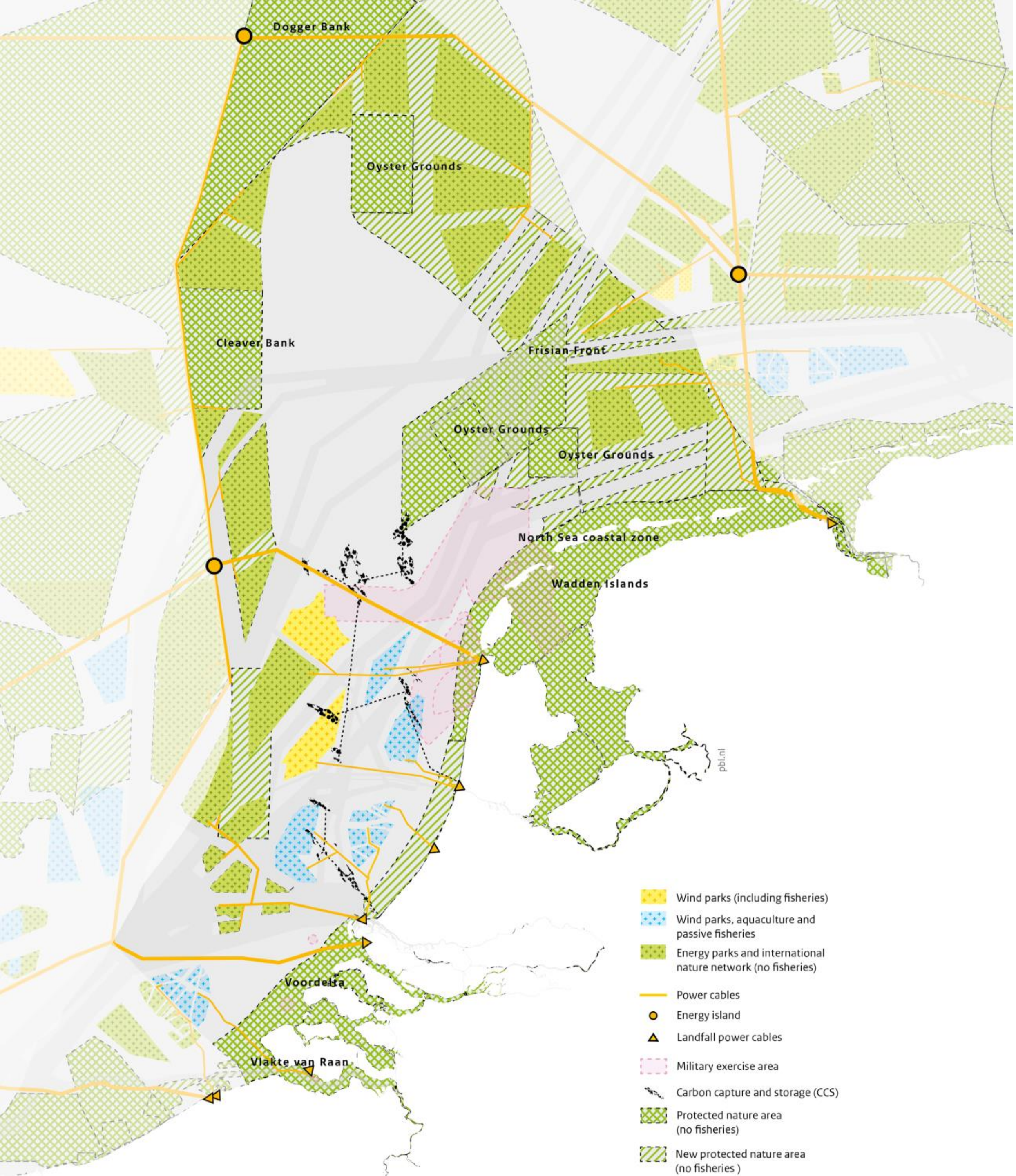
- Cost price of ‘grey’ hydrogen: some €1 – 1.50/kg (but some 13 kg CO_2 footprint)
- Cost price of ‘blue’ hydrogen: ca €2.50/kg (informal information from Norwegian project)
- Cost price of ‘green’ hydrogen:
  - Onshore electrolysis: ca €3 – 4/kg
    - (by 2025 possibly €2 – 3/kg)
  - Offshore electrolysis (including savings on e-grid): €2 – 3/kg
    - (by 2025 possibly €1.50 – 2/kg)
- Note that an EU ETS allowance price increase by €1, implies an increase in the price of a kg of ‘grey’ hydrogen of about €0.01 only.
- So, a more effective allowance price development is probably not sufficient to in itself cover the price gap between ‘grey’ and ‘blue’/’green’ hydrogen; additional PAMs may be needed to speed up

On the scope of power-to-gas

- **The need for 'green' molecules is formidable indeed, if future demand for gas remains roughly the same as now**
- **To illustrate:**
  - Suppose half of 10GW offshore wind capacity will be used for power-to-gas conversion
  - Assume optimum electrolyser capacity related to wind capacity is 80% (NSE1) and 6000 running hours per year for electrolyser
  - Then how much 'green' gas can be generated?

The answer: 4.3 bcm per year (or about 1% of the annual EU28 gas uptake)

- So, if for instance the total annual consumption of natural gas of the Netherlands of some 30 bcm will need to be made 'green' with the help of electrolysis, about 80 GW of offshore wind capacity will be needed, which is about half of the total North Sea wind capacity projected to be installed by about 2050.



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Perspective on the future of the North Sea

source: PBL, 2018

Thank you

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Recent projects and studies:

- Jepma, Van Leeuwen & Hulshof (2017): Exploring the future for green gases, STORE&GO project D8.1 (www.storeandgo.info/downloads)
- Jepma, Spijker & Den Boon (forthcoming 2018): Short-, medium- and long-term perspectives for carbon-neutral gas demand and supply in the EU-28, STORE&GO project D8.5 (www.storeandgo.info/downloads)
- Jepma & Van Schot (2017): On the economics of offshore energy conversion: smart combinations (www.gasmeetswind.eu)
- Jepma, et al. (2018): Towards sustainable energy production on the North Sea – Green hydrogen production and CO2 storage: onshore or offshore? (available on request)
- Jepma, Spijker & Hofman (2019): The Dutch Hydrogen Economy in 2050 – An exploratory study on the socio-economic impact of introducing hydrogen in the energy system of the Netherlands (www.newenergycoalition.org)