Power-to-X costs and scenarios

Danish Energy Day

Montel webinar

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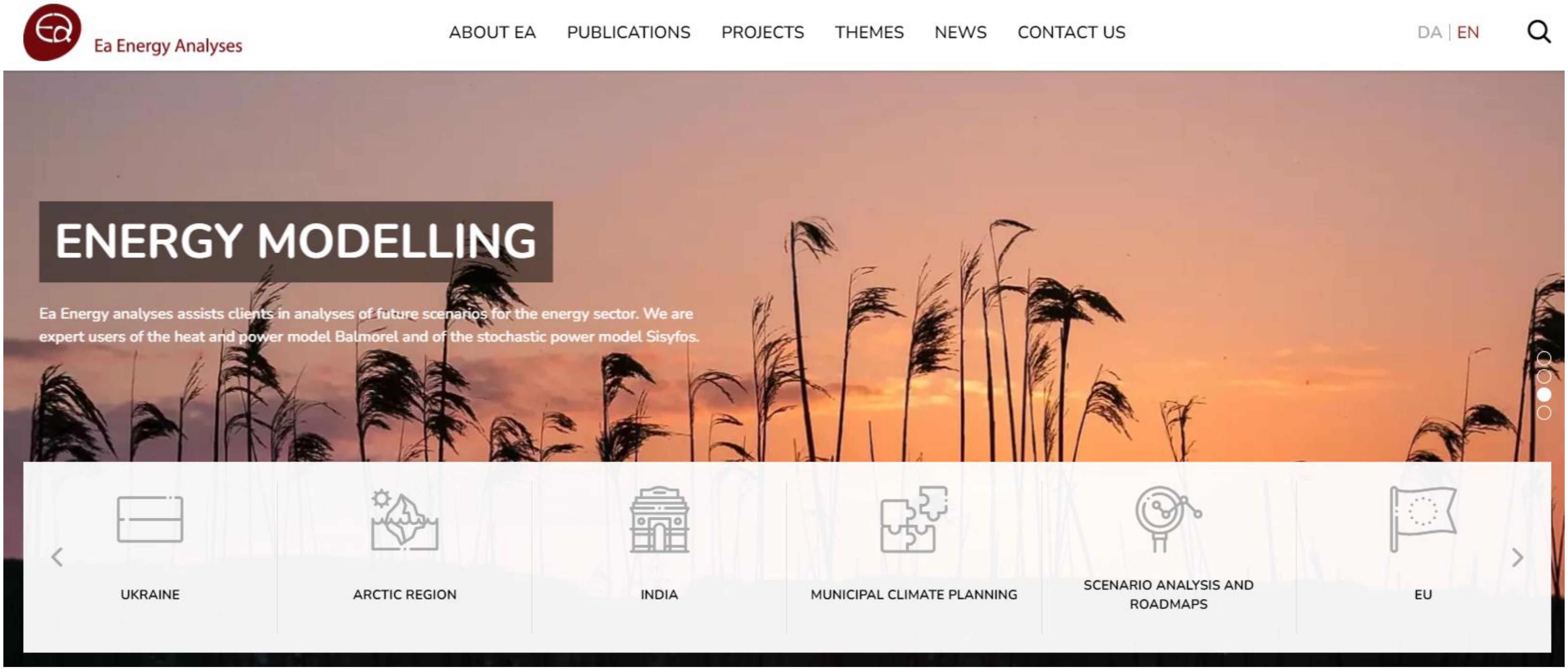

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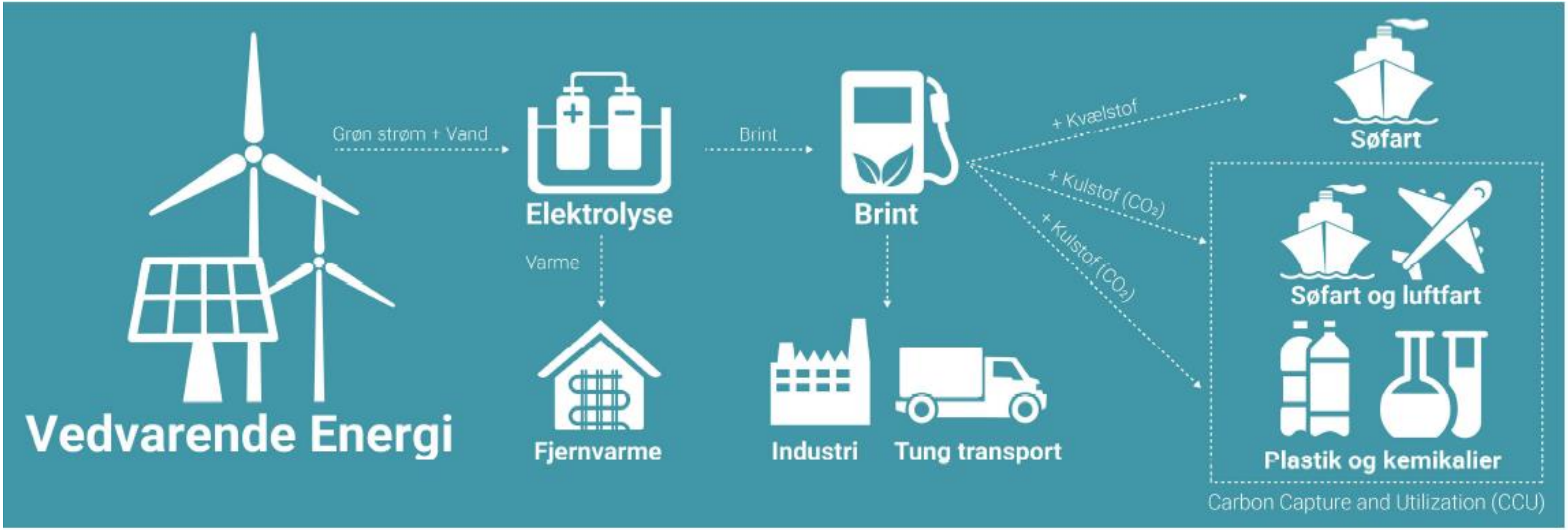
PtX: What and Why?

- **Climate:** PtX fuels is projected by some to become cost-competitive to fossil fuels + CCS + DAC
- **Resources:** Other RE resources (biofuels) are limited and have sustainability issues
- **SoS & Energy dependence:** Europe has abundant wind and solar resources
- **RE integration:** PtX fits with wind and solar as hand in glove

Figure: Regeringens strategi for Power-to-X



Alkaline

Used since 1920'ies for production of fertilisers and chemicals.

Mature & Commercial. Reasonably flexible. (10% - 100%)

Relatively low capex – minimum dependency of rare & costly materials.

Conversion efficiency of 60% - 70% $_{LHV}$ (Incl. BoP)

PEM

Introduced in 1960ies by General Electric. More simple water treatment.

Can be very small & flexible and deliver high pressure Hydrogen

Probably a bit higher CAPEX & OPEX, a bit lower efficiency

SOEC

High temperature, still under development (Lower TRL)

Good perspectives for utilisation of excess heat.

Probably substantially higher CAPEX and OPEX (decay) also in the long term.

Conversion efficiency maybe 90% $_{LHV}$

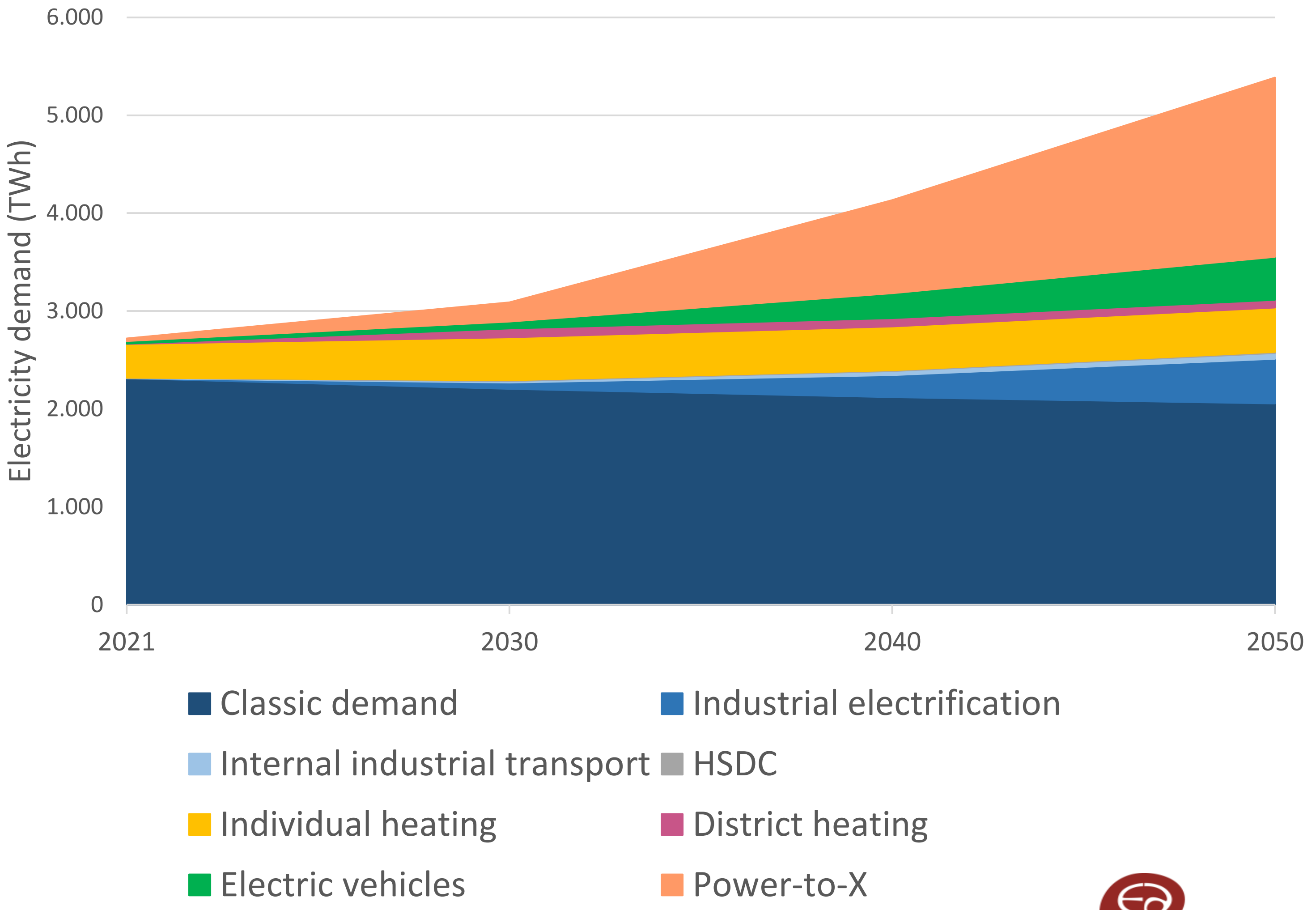
Some PtX strategies in Europe

Note: Pre Ukraine strategies

	2020-2025	2025-2030	2030-2040	2040-2050
EU	Planned investments for >8 GW (mar 2020)	6 GW Electrolyser capacity in 2025	40 GW in EU and 40 GW outside EU in 2030	Green hydrogen in ”Hard to decarbonise” sectors
Germany	2GW in connection to REDII	Demand for 100TWh in 2030. Imports OK.	Discussing incentives, including CfD	
Denmark	1 bio DKK⁺ support	4-6 GW in 2030	Hydrogen infrastructure and incentives	
Sweden		5 GW in 2030	15 GW in 2045	
Norway & Finland	R&D, Commercialisation, international cooperation, support for projects. No quantitative goals. Blue hydrogen?			

FITfor55 translated to demand for electricity

Electricity Demand projection is based on the European Commission's impact assessment for Fitfor55-policies (Fitfor55 2020 - Stepping up Europe's 2030 climate ambition), following the MIX scenario.



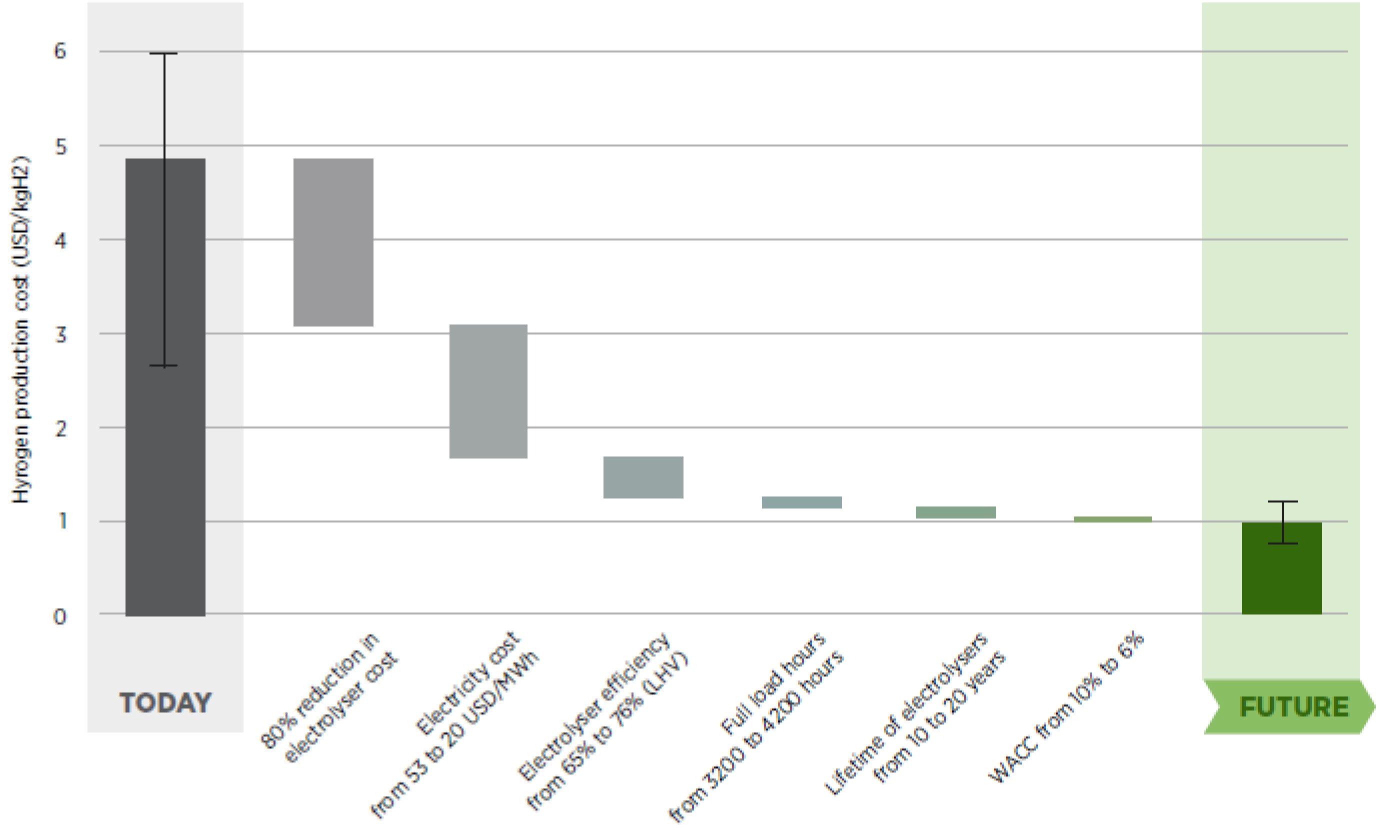
Alkaline electrolysers

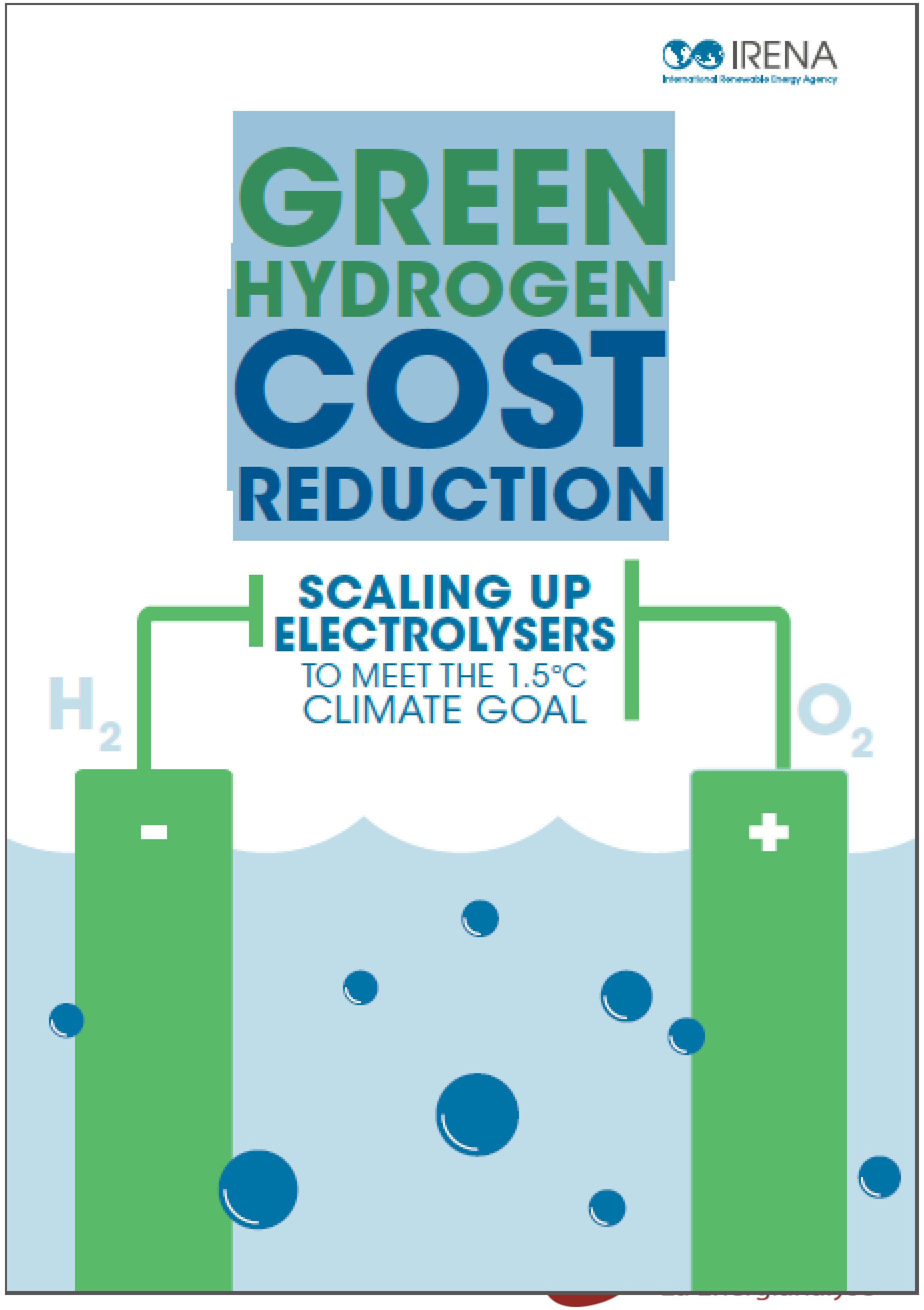
An alkaline electrolyser has an electricity consumption of 4.5-5.0 kWh/Nm. This equals an efficiency of 60-66% at lower calorific value (LHV).

The theoretical maximum conversion from electrical energy to hydrogen energy (without resistance) is 100% at upper calorific value corresponding to 85% at lower calorific value.

63% efficiency$_{LHV}$ is thus 63/85 = ***74% of the theoretical maximum.***

IRENA projection



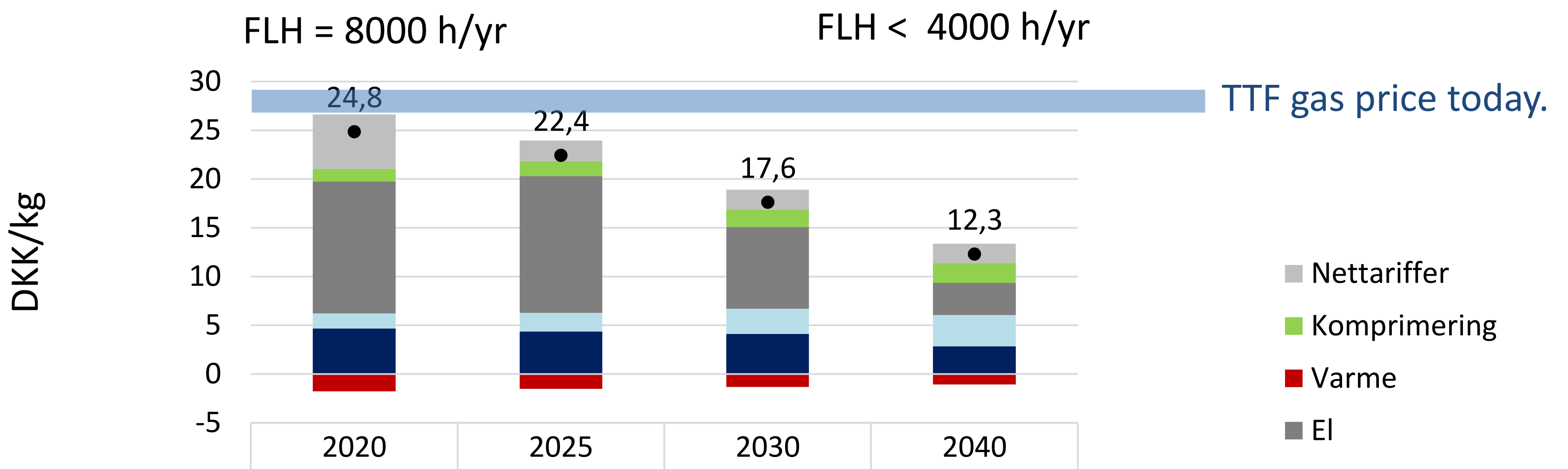


Screening of CAPEX projections for Alkaline

CAPEX (euro/kW-el)	2020	2030
Danish catalogue of technologies	600	550
ICCT assessment	479-1064	454-1013
IEA	500	400
IRENA	840	
Bloomberg	1200	115-135
EU-Commission (Guidehouse)	600-2900	500-1500

In Ea "generic" projections we use the mean estimate for ICCT's literature review in 2020 of 829 euros / kW combined with a learning rate of 15%. With a quadrupling of alkaline capacity by 2030. This yields a 50% CAPEX reduction. We reevaluate based on projects & literature.

Cost of hydrogen – DK1 spotprices pre-ukraine



	2020	2025	2030	2040
Nettariffer	5,56	2,12	2,02	1,97
Komprimering	1,29	1,55	1,80	2,04
Varme	-1,76	-1,52	-1,31	-1,07
El	13,54	14,02	8,41	3,30
Fixed OPEX	1,55	1,89	2,59	3,22
CAPEX	4,67	4,37	4,10	2,83
● Centralt skøn	24,85	22,43	17,61	12,29

1 DKK/kg = 8,3 DKK/GJ (LHV)

Five concluding points

- Flexible dispatch, lower fixed costs & low tariffs are key for competitive hydrogen.
- Vast amounts of green hydrogen and other PtX fuels are necessary to reach climate goals in industrialised countries.
  - In 2050 one third of Europe's total electricity consumption might be electrolyser feedstock.
- Green hydrogen can probably out-compete blue hydrogen from 2035.
  - Hydrogen production based on offshore wind might be competitive to hydrogen production based on North African solar. The cost of transport infrastructure is decisive.
- CAPEX reduction, flexible operation and green electricity are necessary prerequisites.
- Most important issues to solve:
  - **Short and long term:** More rapid buildout of wind and solar. This is urgent.
  - **Long term:** Green carbon resources for synthesis from Hydrogen to Hydrocarbons.

Thank you for your attention