



Power-to-X in Denmark

Danish Energy Agency
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Agenda

- Introduction
- Power-to-X drivers
- The Danish strategy for Power-to-X
- Key messages from the Danish Power-to-X analyses
- Status on Power-to-X in Denmark

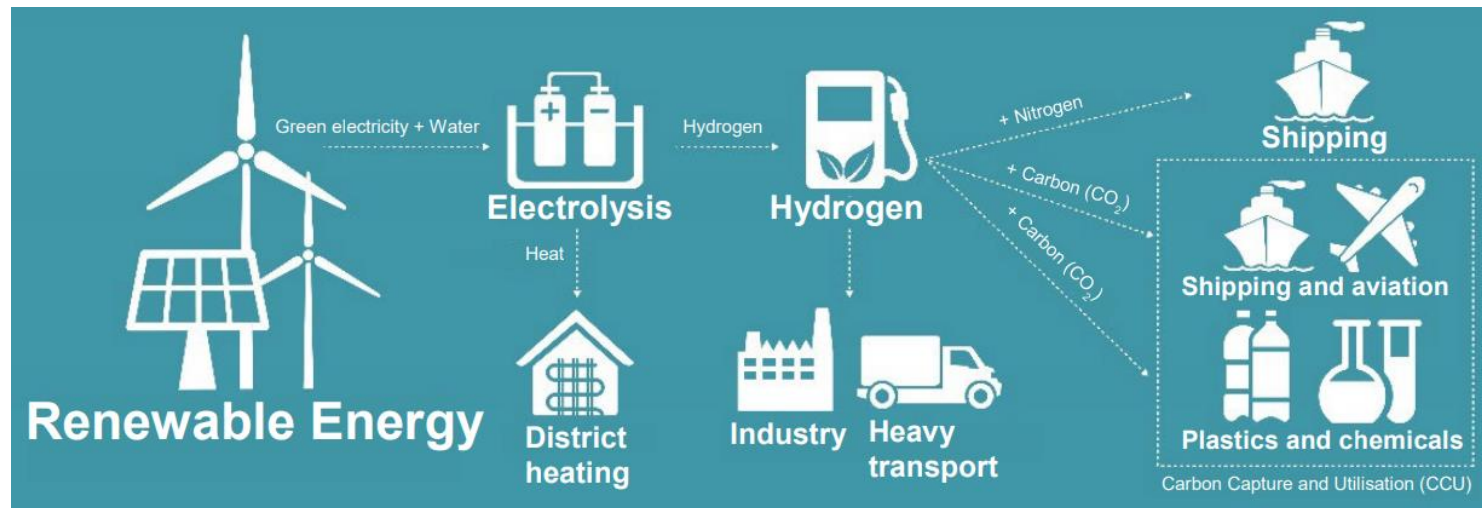




INTRODUCTION

WHAT DO WE MEAN BY POWER-TO-X (PTX)?

"Green electrons as input and green molecules as output"



Product examples: Hydrogen (H₂), Ammonia (NH₃), Methanol (CH₃OH), Methane (CH₄) and Kerosene (C₁₂H₂₆-C₁₅H₃₂)



DRIVERS FOR POWER- TO-X IN DENMARK

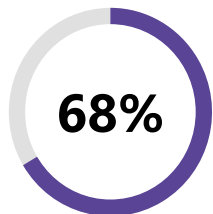




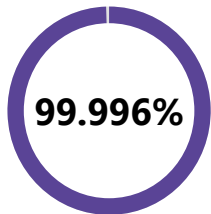
LARGE SHARE OF RE AND AN AMBITIOUS CLIMATE POLICY

STATUS in DK

RENEW POWER IN
POWER CONSUMPTION



SECURITY OF
SUPPLY

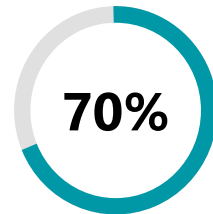


TARGETS in DK

GREEN POWER
IN 2030



CARBON REDUCTION
IN 2030



CLIMATE NEUTRALITY
IN 2045



CARBON REDUCTION
IN 2050



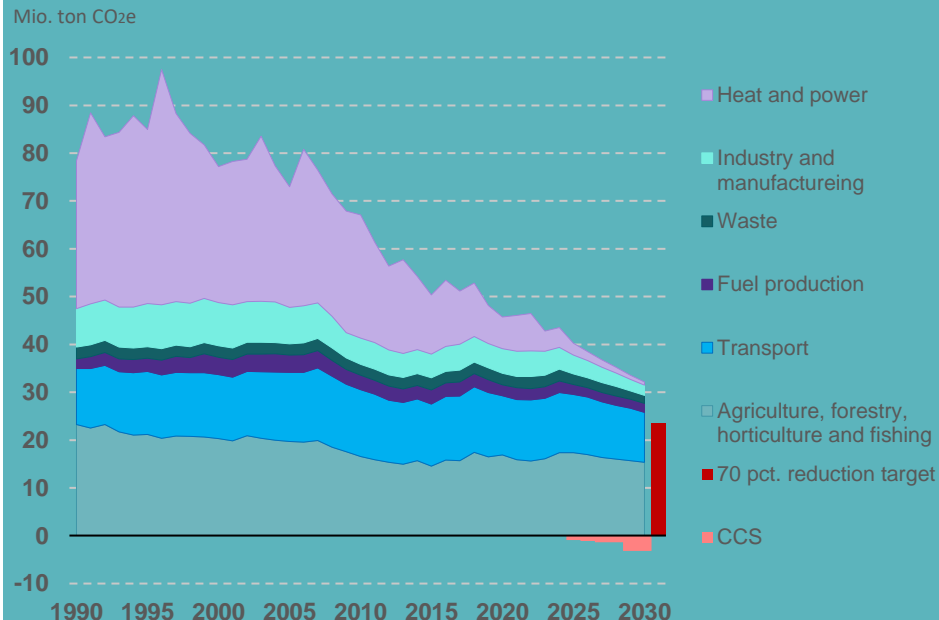


EMISSIONS ARE DECLINING

- *But not in every sector*

- The green transition is on its way in **energy and utility sector** and the **industry**
 - Further reductions in these sector are limited and costly.
- Fulfilling targets in 2030, 2045 & 2050 requires reductions or compensation in hard-to-abate-sectors e.g. **transport** and **agriculture**
- Direct electrification solve part of the challenge in **transport sector** and **industry**
 - However there are a need for renewable fuels in specific segments
- **Power to X** is expected to play a large role within Shipping, aviation, heavy transportation and some industries

Total national emissions, KF23



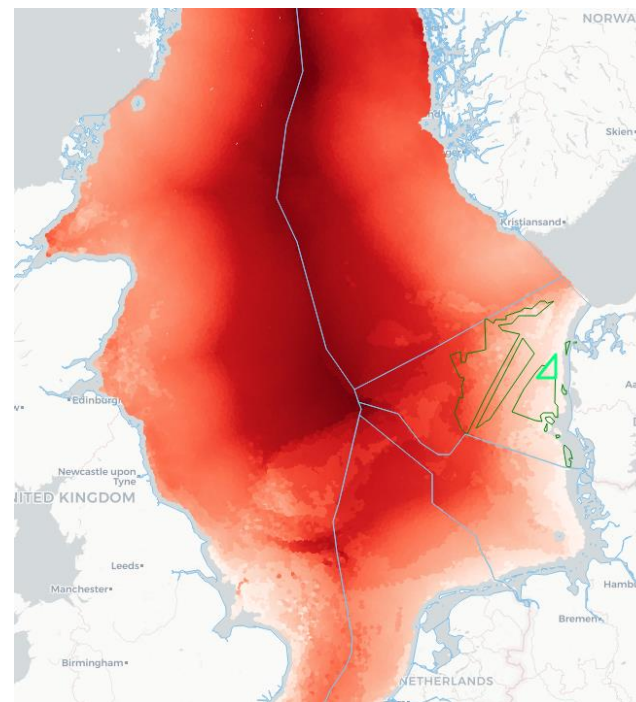
POWER-TO-X PRODUCTION POTENTIAL IN DENMARK

Energy system in Denmark and Power-to-X

- Increasing share of the electricity consumption is based on renewable energy. In 2020 the share was 68%.
- The North Sea offers a substantial offshore wind resources with competitive electricity costs and a well developed and functioning electricity grid.
- Flexible PtX plants located near RE resources enables lower demand for grid expansions.
- Extensively developed district heating grid enables utilization of excess heat from PtX.

Know-how and partnerships:

- Know-how in all parts of the value chain
- Partnerships for PtX, aviation, shipping etc.



Levelized Cost of Electricity, DKK/MWh





THE STRATEGY FOR POWER-TO-X IN DENMARK



STRATEGY FOR POWER-TO-X

A new and rapidly developing agenda

- The Climate Agreement for Energy and Industry 2020:
 - Agreement of the Danish Parliament to prepare a Danish strategy for Power-to-X (PtX) and Carbon Capture and Utilization (CCU).
- The Government's strategy for Power-to-X – December 2021.
- Based on more than 20 analyses totalling more than 500 pages.
- Simultaneously the PtX agenda has accelerated.
- More than 35 Power-to-X projects has been announced in Denmark totalling more than 9 GW combined





OBJECTIVES IN THE STRATEGY FOR PTX

The strategy presents four objectives for the development and utilization of Power-to-X in Denmark

The objectives sets out the guiding principles for the use of PtX-technology, hydrogen and fuels in Denmark:

1. PtX is to be used in the green transition, where it is the cheapest and most sustainable option.
2. Framework and infrastructure must enable the development of PtX to a point where it is competitive with biofuels and PtX suppliers from abroad on market terms.
3. PtX-production has to happen in a way where it creates value for the Danish energy system.
4. The reason for promoting production of hydrogen and PtX-fuels in Denmark is to support industry and export markets.

Objective 1

Power-to-X must be able to contribute to the realisation of the objectives in the Danish Climate Act

Objective 2

The regulatory framework and infrastructure must be in place for Denmark to utilise its strengths and allow Power-to-X to perform on market terms as soon as possible

Objective 3

The integration between Power-to-X and the Danish energy system must be improved

Objective 4

Denmark must be able to export Power-to-X products and technologies



AGREEMENT ON HYDROGEN AND PTX & THE NEXT STEPS

Adoption of the strategy by Parliament

Content of the agreement:

- Target of 4-6 GW electrolysis capacity by 2030
- One tender of 1.25 billion DKK, as a production subsidy for 10 years – to be launched in 2023
- Direct connections of RE-production and consumption
- Geographically differentiated electricity tariffs
- 57 mill. DKK in 2022-2026 for a PtX-taskforce
- First steps towards establishing a hydrogen infrastructure enabling export to Germany

Green reform (June 2022):

- Renewable energy package (done)
 - Ensuring sufficient green electricity and zoning for RE and PtX
- CO₂ tax on industry and domestic transportation
 - Support schemes for transition in industry and transportation

Upcoming national proposals (2022-23):

- Hydrogen infrastructure package – first steps
- Policy proposal for green road transport (passengers and heavy transportation)
- New proposal on CO₂ tax on flights

New EU-legislation (*Fit-fo-55*):

- ReFuelEU Aviation – *blending mandates*
- ReFuelEU Maritime – *blending mandates*
- Renewable Energy Directive II – *CI-demands*



POWER-TO-X TENDER

- *"A tender to support [...] Power-to-X plants should contribute to reduce production costs of green hydrogen".*
- 1,25 billion DKK. funded from sales of renewable energy shares to the Netherlands.
- State aid rules from European Union do not allow demand for use of PtX products in Denmark when have received state aid.
- Operational support for Danish production of PtX products.
- Fixed price premium for up to 10 years.
- Competition on support for quantity of hydrogen – no matter the end product.
- Contributing to industrialize and reduce the costs of PtX technology and PtX products.

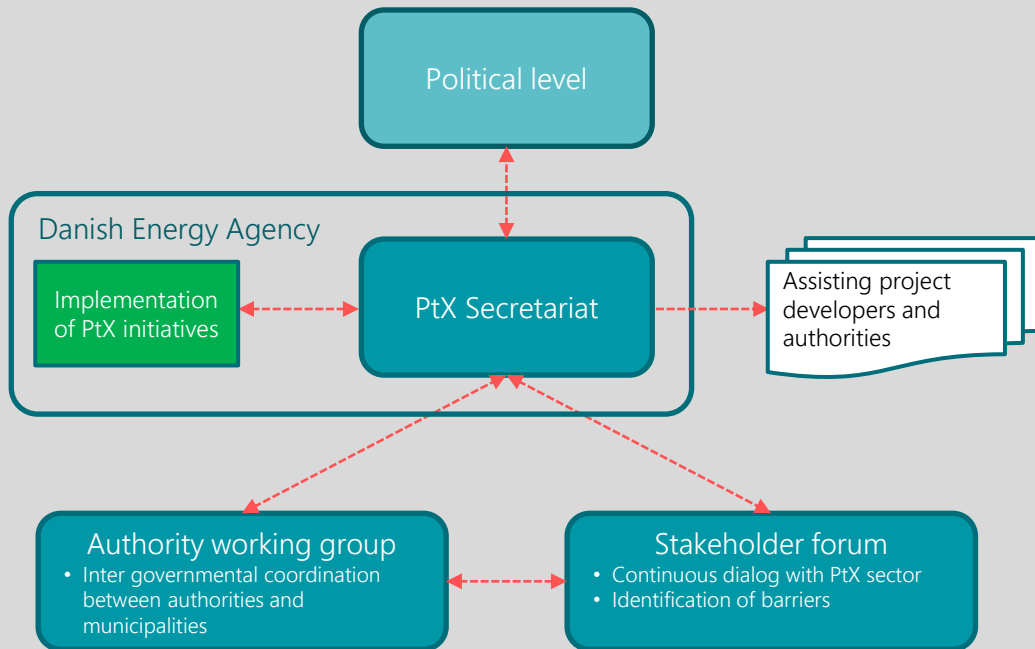


Illustration: Biogas and coming PtX plant: GreenLab Skive



ORGANIZATION OF POWER-TO-X TASKFORCE

Power-to-X Taskforce




Purpose

The PtX-Taskforce contributes to coordination between public authorities and ensures dialog between municipalities and the PtX sector.

The purpose of the PtX-Taskforce is to identify and solve regulatory barriers for developing a new utility sector in Denmark.

Moreover it is the purpose to ensure common rules for documentation of green hydrogen and develop tools that supports optimal socioeconomic location of PtX-plants.

Part of the PtX-Taskforce is a PtX Secretariat, which will be point of contact and support project developers and authorities with guidelines regarding permit procedures etc.



KEY MESSAGES FROM THE
DANISH POWER-TO-X
ANALYSES



COMPETITIVENESS WITH BIOFUELS (MEDIUM-LONG TERM)

"Costs of electricity consumption dominate hydrogen production costs"

Estimated costs of green hydrogen production

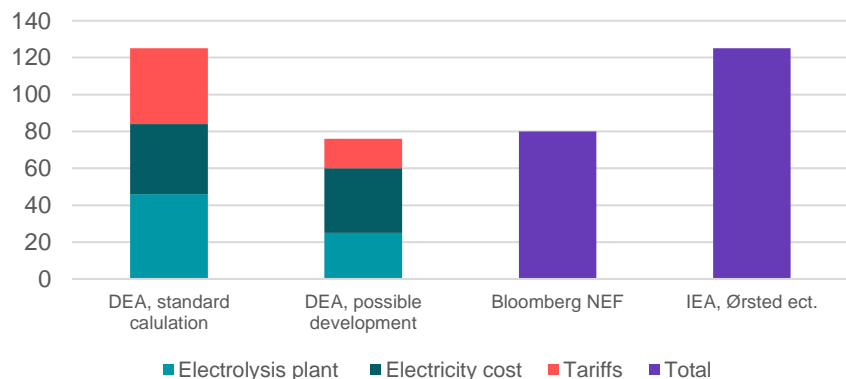
Considerable potentials for lowering production costs through:

- Scaling and industrialization of electrolysis technology and plants
- Appropriate regulation

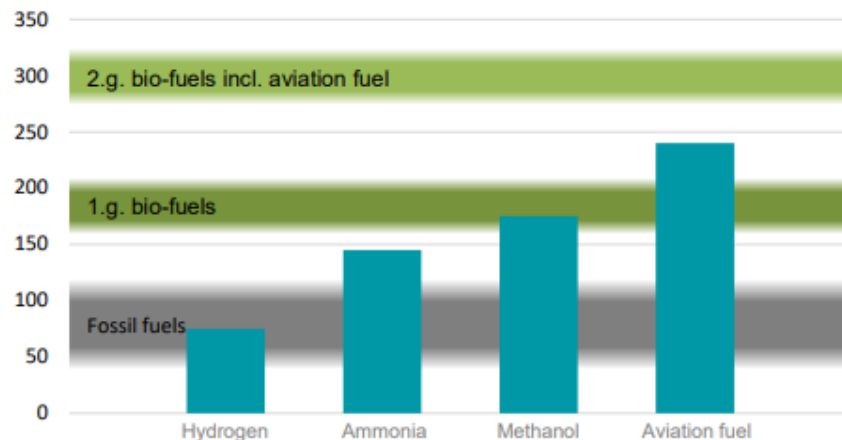
Competition with other fuels

- E-fuels (E-Ammonia, E-methanol and E-kerosene) cannot compete with fossil fuels on the medium term if ever
- E-fuels are expected to be competitive compared to 2. generation biofuels on the medium-long term.

Production cost for green hydrogen (DKK/GJ)



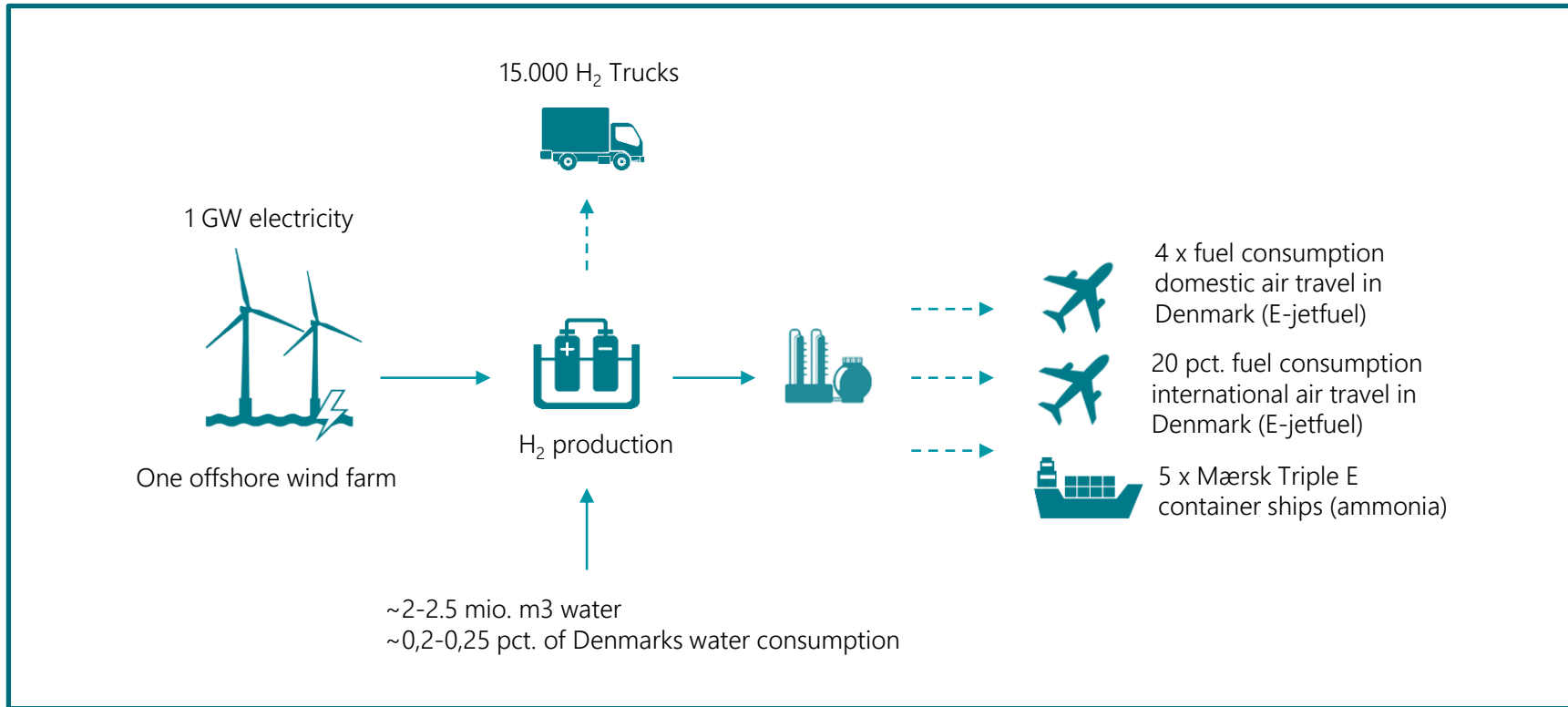
Long-term forecast of production costs for PtX fuels (DKK/GJ)





ENERGY BALANCE

Annual consumption



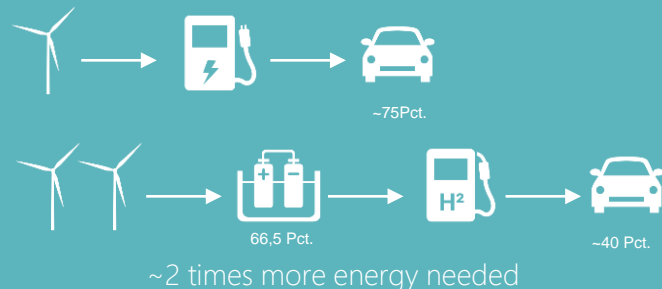
POWER-TO-X VS. DIRECT ELECTRIFICATION?

Examples of energy efficiency through electrification

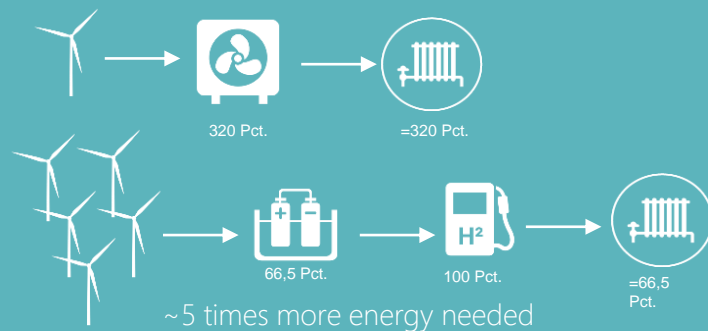
- Energy demand for electrification and Power-to-X
 - A hydrogen powered vehicle requires more than double the energy compared to an electrical vehicle
 - A hydrogen boiler for space heating requires approx. five times the energy compared to a heat pump
- More efficient Power-to-X technologies are being developed, but direct electrification is often the best option and should be prioritized wherever it is possible
- Too early utilization of Power-to-X can delay green transition and GHG-reductions

Energy demand for direct electrification and Power-to-X

Electrical vehicle vs hydrogen powered vehicle



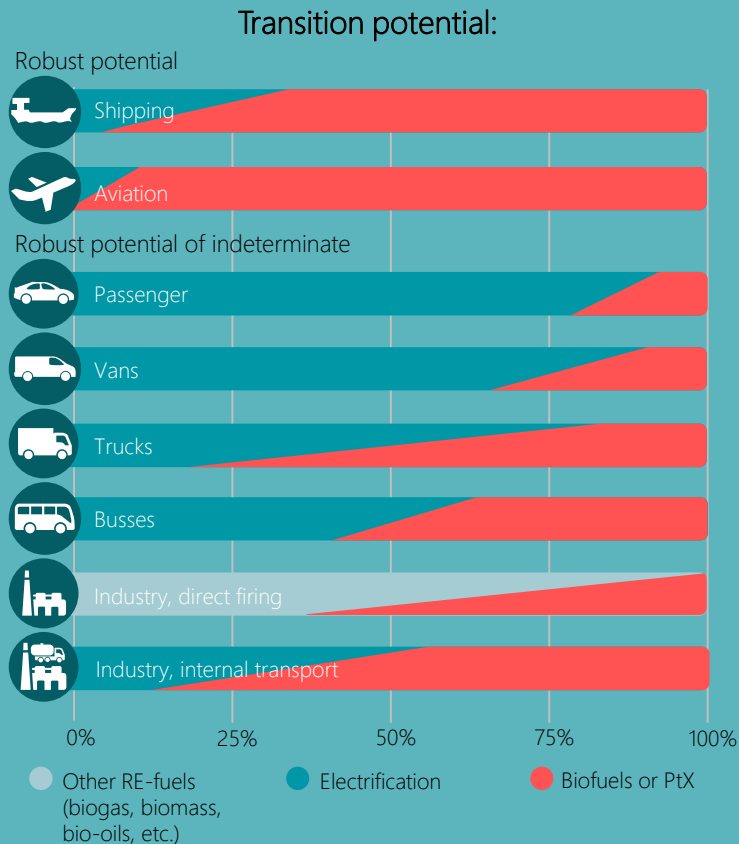
Space heating: Heat pumps vs hydrogen boilers






UTILIZATION OF PTX IN DENMARK

- Power-to-X will remain more expensive than direct electrification where that is applicable.
- Green hydrogen and e-fuels are expected to become cheaper than advanced biofuels (medium-long term).
- Fairly certain of dominant position within shipping and aviation.
- More uncertain in other parts of land based transportation, industry, agriculture and defense.
- No role in heating or electricity generation in Denmark as cheaper options exist:
 - Heat pumps and district heating for space heating
 - Biogas for peak electricity production

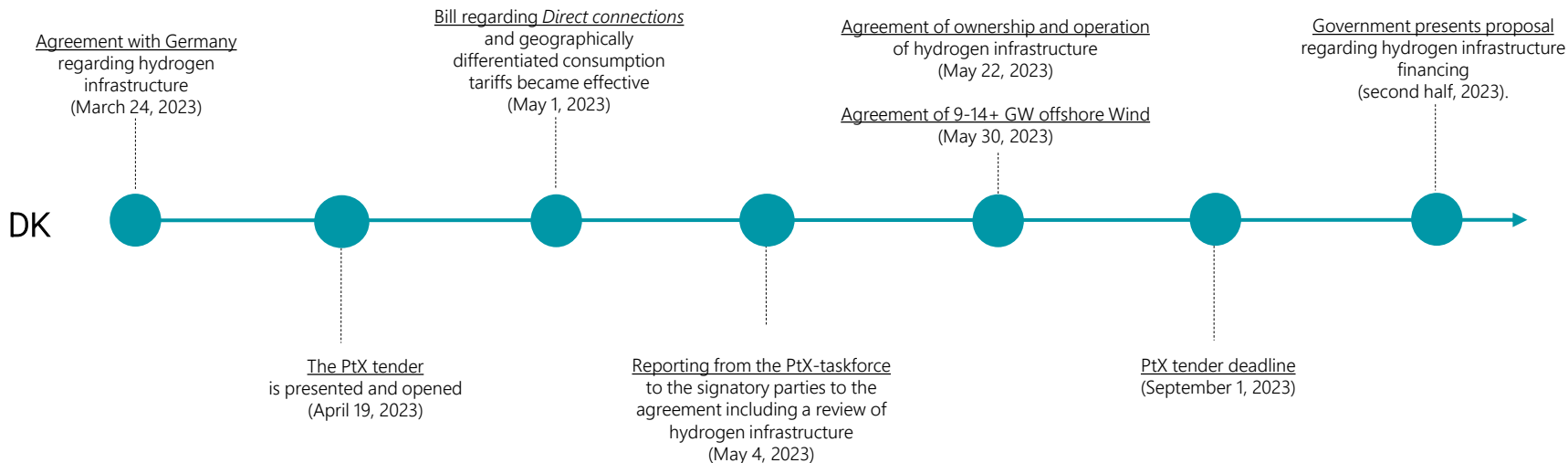




STATUS ON
POWER-TO-X IN
DENMARK



STATUS AND DEVELOPMENT IN POWER-TO-X



EU

Hydrogen and gas market package
 General attitude known.
 Negotiations expected in second half 2023.

EU's delegated act
 Requirements for production of green hydrogen and PtX fuels.
 Binding from July 2023

Demand side regulation
 REDIII directive and ReFuelEU
 Aviation finalized negotiations
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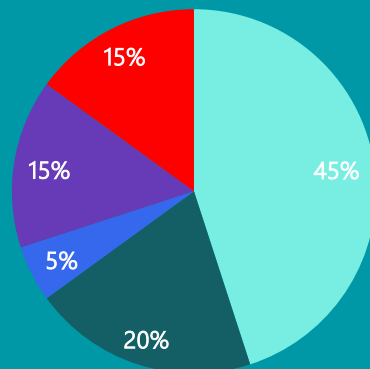
STATUS ON DANISH PTX PROJECTS

 Announced PtX-projects

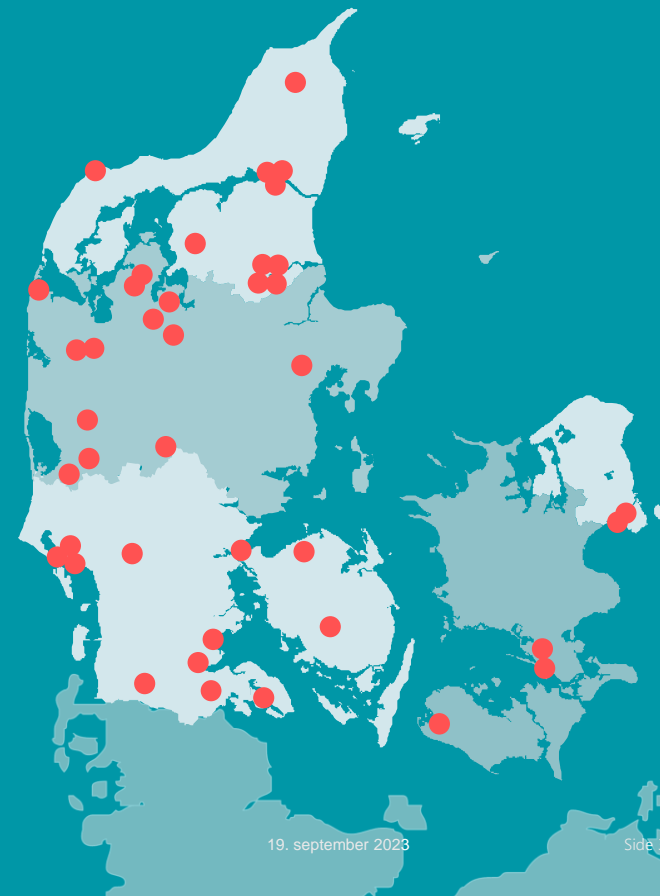
- More than 35 announced projects constituting more than 9 GW electrolysis capacity by 2030.
- The projects are planned to be commissioned between 2023- 2030.
- The projects varies in size (5 – 2.000 MW) and end product.

Examples of projects commissioning in 2030:

- HySynergy – hydrogen production by 20 MW electrolysis
- European Energy, Kassø – methanol production by 52 MW electrolysis



 Hydrogen  Methanol  Metane
 Ammonia  Kerosene



An aerial photograph of a port area with a large white circle overlay in the center. The circle contains the text "Thank you - Any questions?". To the left of the circle are two overlapping teal circles. The background shows a harbor with a large red and white ship, several tall cranes, and stacks of blue and red shipping containers. The sky is clear blue.

Thank you -
Any questions?

