# SYSTEM PERSPECTIVES OF THE 70%-TARGET AND LARGE SCALE OFFSHORE WIND

## Executive summary and main conclusions

*Energinet Electricity System Operator*

# LONG TERM FOCUS SUPPORTS ROBUST DECISIONS TODAY IN THE ELECTRICITY AND GAS SYSTEM

## The energy sector is changing extensively – and Energinet is getting ready

- Energinet Electricity System Operator develops system perspective studies and scenarios in order to create a long-term outlook for the future development of the energy system. This is done to prepare the energy system for accomodating a wide range of possible outcomes of the future.
- Infrastructure solutions developed today typically have a life time of 40 years or more. It is essential to understand, which possible future the infrastructure solutions of today should be able to support.

## System perspective studies provide input for Energinet's planning and innovation work

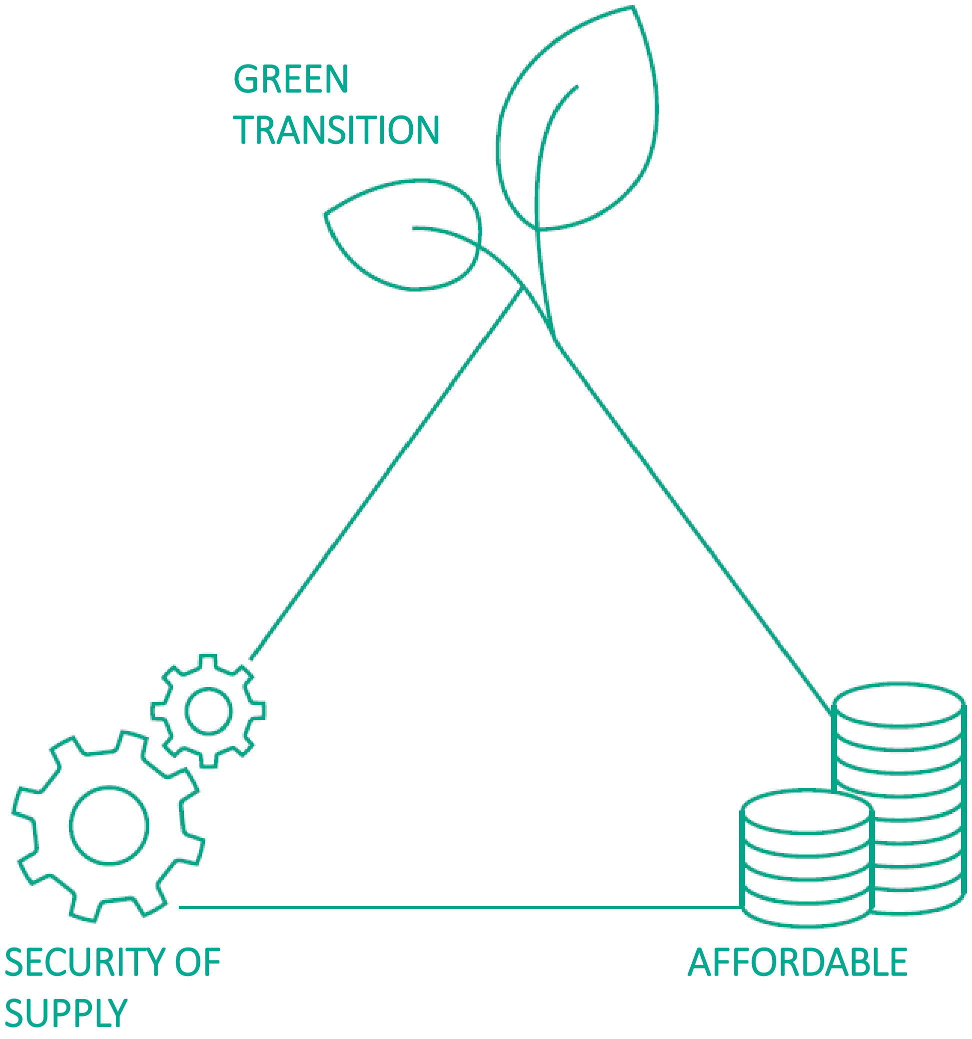
- The development of the long-term scenarios in the system perspective studies are actively used as input for Energinet Electricity System Operator's planning and innovation work (e.g. in Energinet's long-term development plan).
- The system perspective studies are not a development plan per se but the studies should visualise different possible development routes and thereby create additional scenarios around Energinets central basis for planning (The Danish Energy Agency's Analysis Assumptions for Energinet).

# ENERGINET PREPARES FOR THE FUTURE

*The system perspective study analyses the consequences for the electricity- and gas system of the 70 % reduction target and more offshore wind*

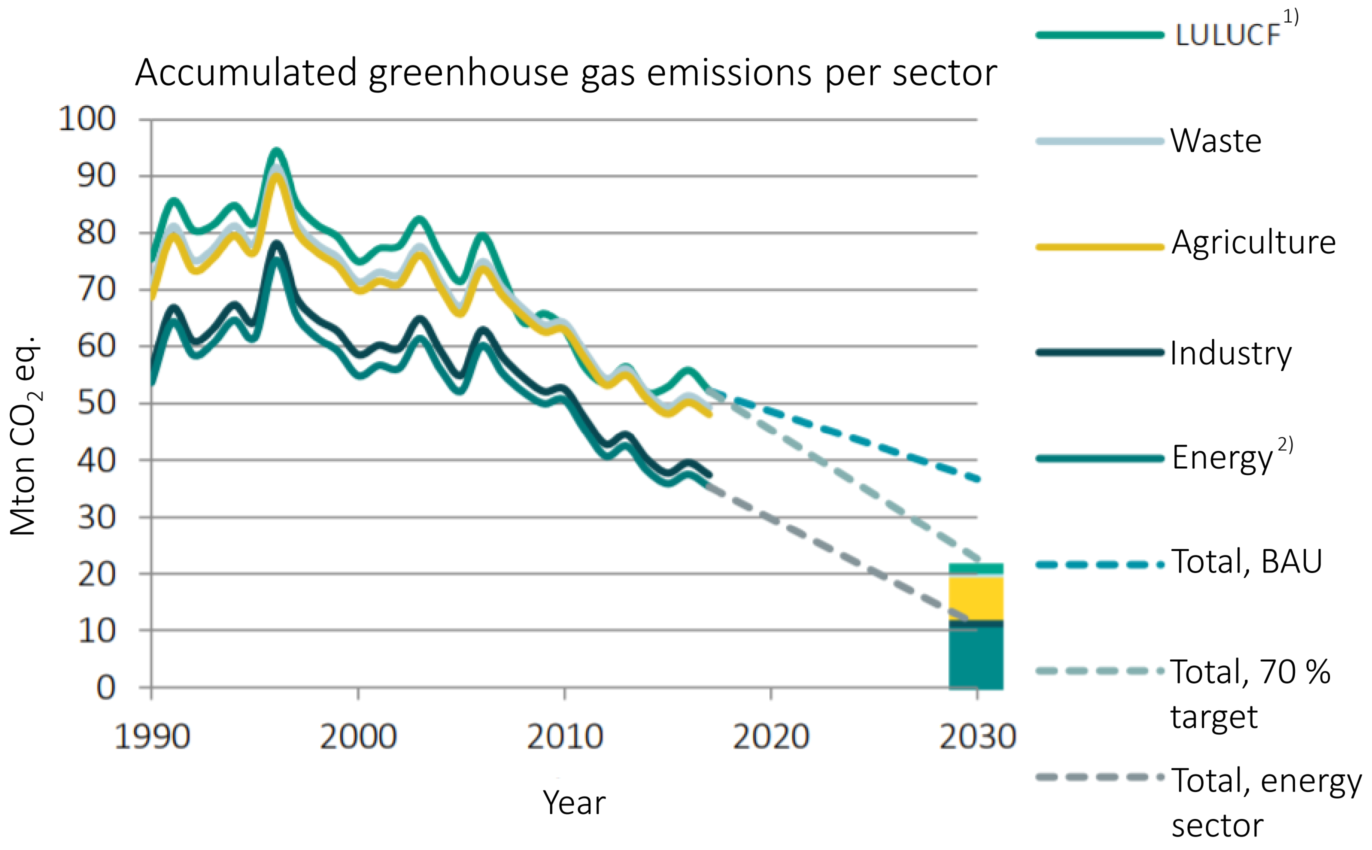
The study contains the following three sections:

- A focus study with examples of possible development routes for a Danish energy system compliant with the 70 % reduction target in 2030 (section 1)
- A long-term system analysis which examines the perspectives of utilising large-scale offshore wind in 2035 (section 2).
- A summary of selected focus areas for Energinet Electricity System Operator in relation to the 70 % reduction target, utilisation of large-scale offshore wind and the long-term planning and development of the electricity system (section 3).



# SECTION 1:
# SYSTEM PERSPECTIVE STUDY OF ACHIEVING THE 70 % REDUCTION TARGET BY **2030**

# THE 70 % REDUCTION TARGET: A POSSIBLE, BUT AMBITIOUS TARGET




The 70 % reduction entails that:

- The $CO_2$ emission for the society should be reduced to 22,5 Mton $CO_2$ equivalents

Reductions in all sectors are most likely needed in order to achieve the 70 % target. **Two examples of possible reduction routes** (with assumptions for reductions in other sectors) gives:

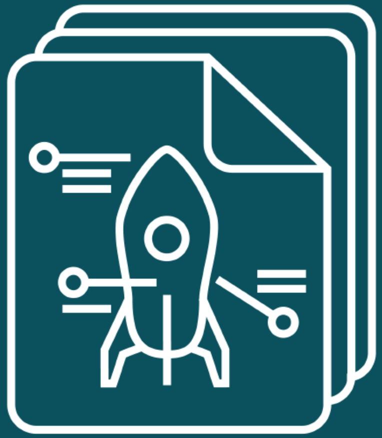
- The emission from the energy sector should be reduced to 10-12,5 Mton $CO_2$/year
- The energy sector is defined as all national energy related emission including national transport, but excluding international aviation and shipping.

*1) Effect of changes in land use and forestry.*
*2) Energy incl. domestic transport.*

# 10-12,5 MTON $CO_2$ DEMANDS REDUCTIONS IN THE VALUE CHAINS

With a scope of 10-12,5 Mton CO2 a significant restructuring in the energy sector is needed. This requires reductions in the entire value chain (e.g. production, conversion and end-use of energy).

In this system perspective study, the energy sector is divided into 7 categories.



# THE SEVEN CATEGORIES OF THE ENERGY SECTOR

- Electricity and district heating production
- Oil- and gas production (offshore/refinery)
- Process heat for industry/service
- Light transport(passengers and delivery vans)
- Individual heating of buildings
- Heavy duty transport(truck, bus, planes, ships)
- Green fuel production including biogas and PtX

## Electricity and district heating production

- Continued phase-out of coal fired power plants
- Installation of large-scale heat pumps in district heating
- Transition to RE electricity production (solar and wind)

## Oil and gas production

- Efficiency improvements in oil and gas extraction in the North Sea (e.g. Tyra)
- Electrification of North Sea activities

## Process heat for industry/service

- Electrification of process heat
- Reduction of coal and coke; replaced by heat pumps and gas
- Addition of hydrogen in the natural gas network

## Light transport

- Roll-out of green vehicles (electric vehicles and plug-in hybrids)
- Hydrogen added to fossil diesel

## Individual heating of buildings

- Individual oil boilers replaced by individial heat pumps
- Half of the individual natural gas boilers are replaced by electric heat pumps and hybrid heat pumps
- Installation of new district heating network

## Heavy duty transport

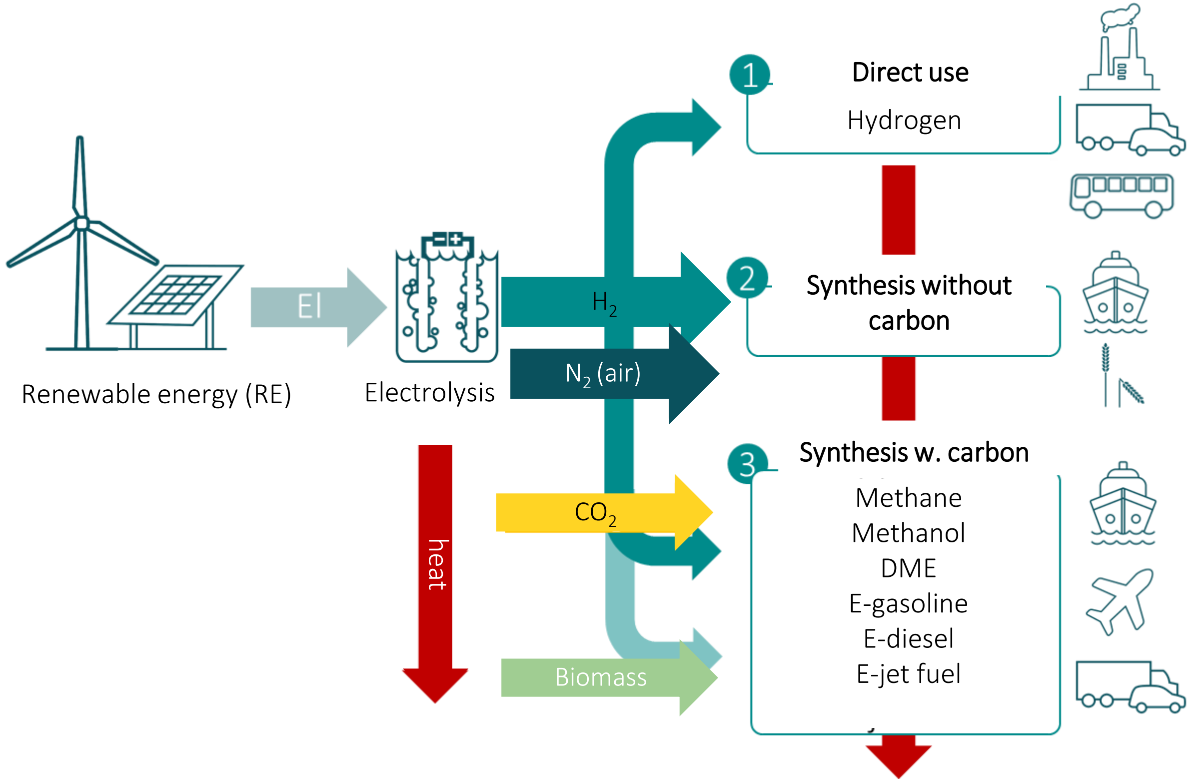
- Usage of RE-fuels via PtX
- Hydrogen added to fossil diesel
- Roll-out of hydrogen busses (and a smaller amount of hydrogen trucks)

# GREEN FUEL PRODUCTION

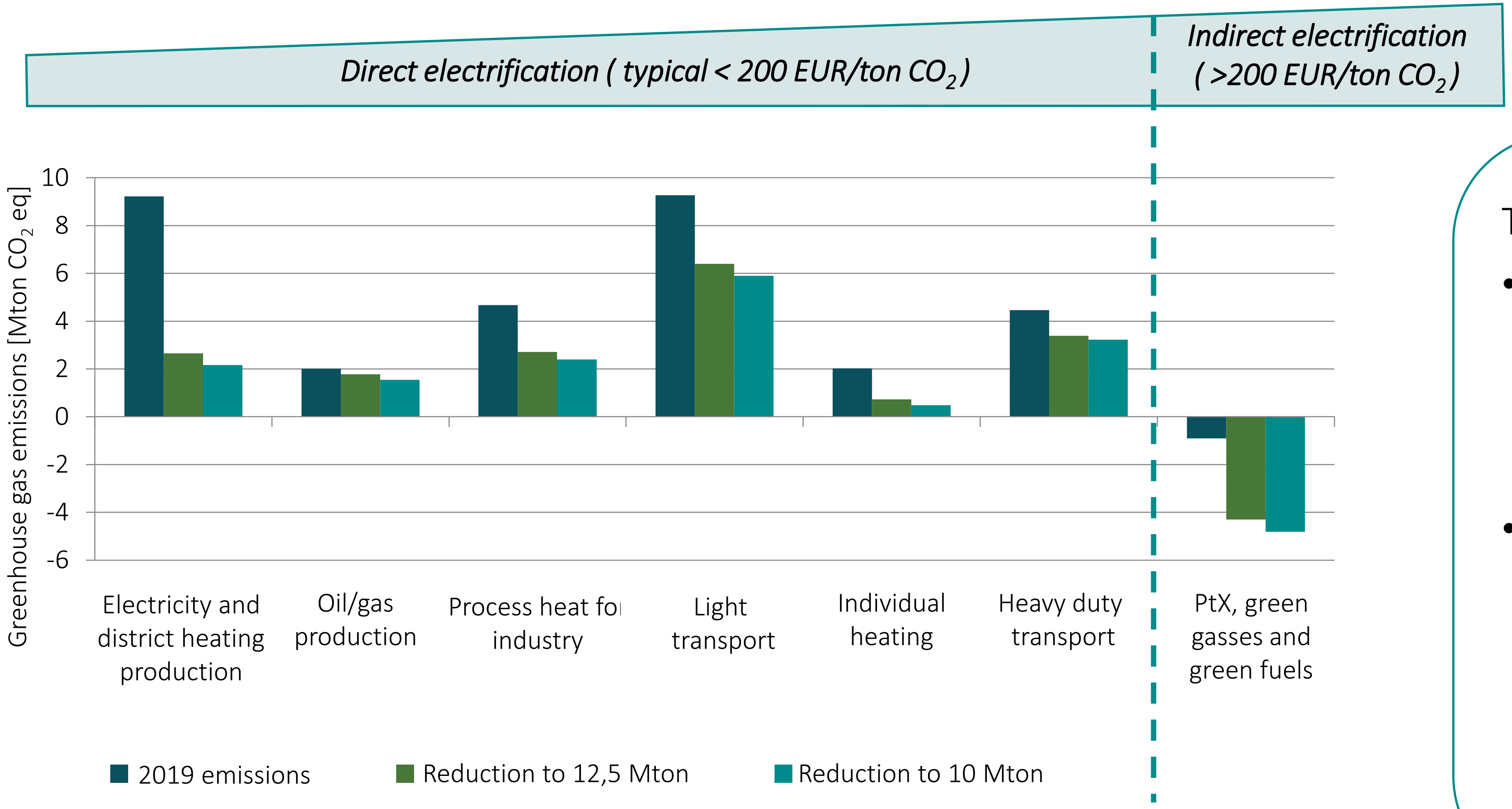
Production of RE-fuels (gaseous or liquified) can replace fossil fuels in the energy system. RE-fuels are produced through a range of processes which start by converting the renewable electricity to green hydrogen via electrolysis. The green hydrogen kan either be used directly in e.g. heavy duty transport or further refined to a wide range of PtX-products. Some PtX-products require a carbon source (from $CO_2$), while other products does not require a carbon source (e.g. ammonia).

PtX initiatives in the 10-12,5 Mton $CO_2$ reduction routes:

- Expansion of the biogas production
- Increasing amount of straw in the biogas production
- Formation of energy clusters with PtX and energy industry (e.g. thermal gasification, biogas plants and bio-based combined heat and power plants)



# A 70 % REDUCTION REQUIRES SIGNIFICANT DIRECT AND INDIRECT ELECTRIFICATION




The study finds:

- PtX is *one* solution among others for reaching the reduction target, but PtX is an expensive reduction measure in the short term.
- Production costs for PtX-fuels can be reduced by:
  - Combining electricity and gas infrastructure
  - Geographic markets and flexibility

# THE 70 % REDUCTION TARGET IMPACTS THE ELECTRICITY DEMAND AND THE NEED FOR RENEWABLE ENERGY

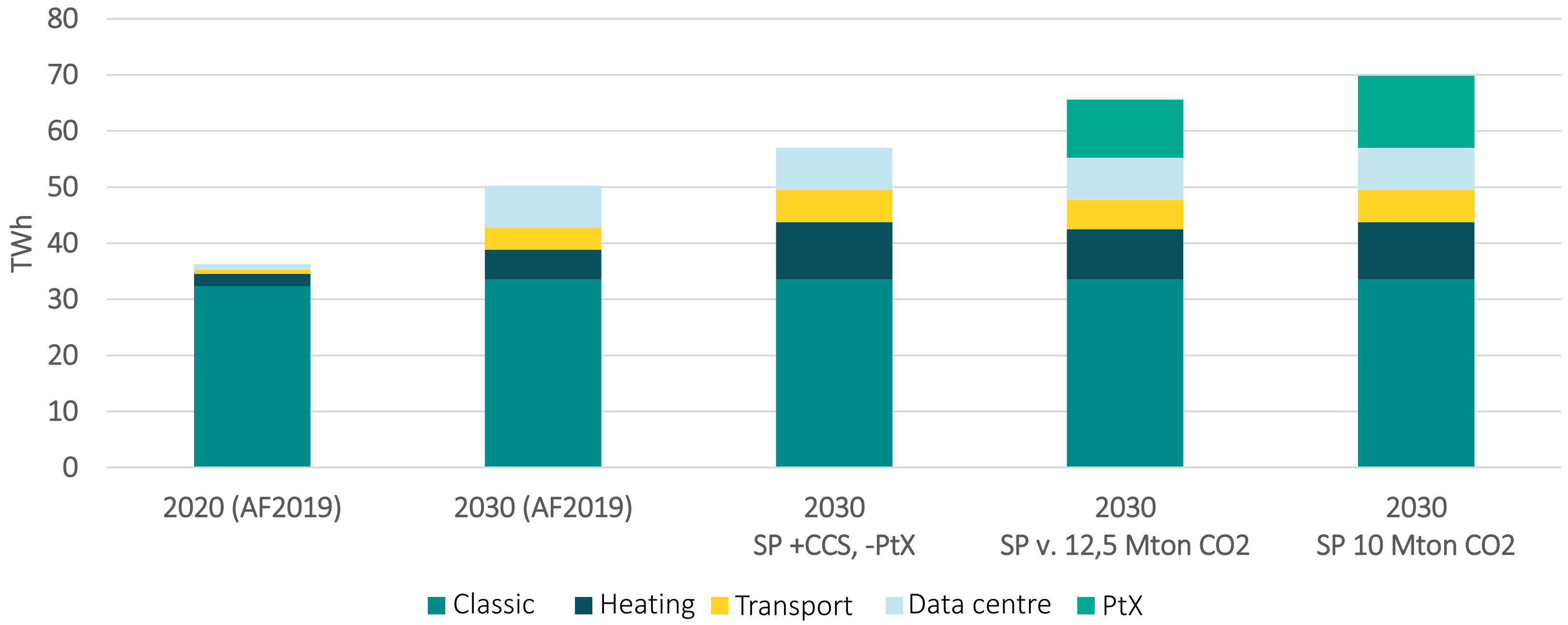
## The reduction target is achievable, but may increase the electricity demand significantly

- The study shows a demand for a significant direct electrification of heating, industry and the transport sector. However, these measures alone are not sufficient to realise the reduction target. There is also a need for a focused effort within the field of production of green fuels.
- Production of green fuels via PtX as a contribution to the 70 % reduction target is *one* solution among others.
- CCS (carbon capture and storage) in combination with import of green fuels can within the time horizon of the 2030 reduction target be an alternative to national PtX-production. It is also possible that other sectors than the energy sector can provide larger emission reductions than assumed in this study.

## Need for more renewable electricity production to cover the electricity demand

- The Analysis Assumptions 2019 (AA19) assumes approx. 5 GW offshore and nearshore wind farms and approx. 6,6 GW photovoltaics, which are expected to produce 40 TWh electricity. In addition, electricity production from centralised and decentralised power plants amounts to approx. 10-15 TWh.
- If the electricity production in 2030 should meet the demand, additional renewable electricity production is needed compared to the reference (AA19). This can be achieved by combining wind power and solar power. A one-sided build-out of solar power will require a significant amount of seasonal storage of energy.
- The need for additional renewable production capacity in order to realise the 70 % reduction target in 2030 may lead to deployment of offshore wind. However, seen in isolation it is not necessary to realise all 10 GW extra offshore wind by 2030. A large-scale deployment of offshore wind is especially interesting in the longer term in relation to the transition towards climate neutrality and utilisation of the Danish offshore wind potential in an international perspective.

# POSSIBLE DEVELOPMENT ROUTES FOR THE FUTURE ELECTRICITY DEMAND




| | | | | | |
|---|---|---|---|---|---|
| Electricity consumption, TWh | 36 | 50 | 57 | 66 | 70 |
| Extra offshore wind[1] at ref. PV | - | - | 1 GW | 3 GW | 4 GW |
| Extra offshore wind[1] at extra PV[1] | - | - | 0-1 GW | 1-2 GW | 2-3 GW |

*[1]On top of the capacity assumed in AA19.*

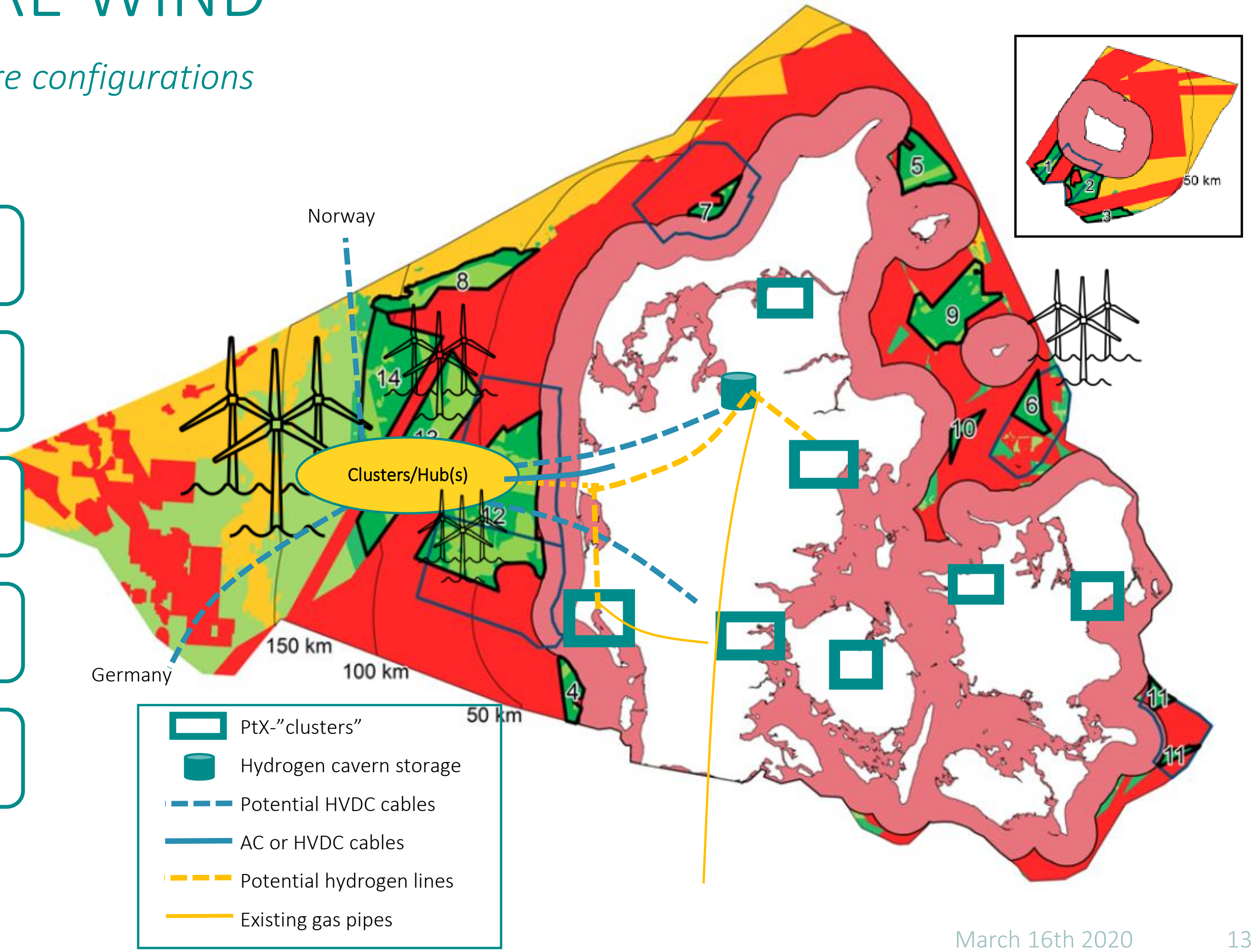
# SECTION 2:

# SYSTEM PERSPECTIVES FOR **2035** TOWARDS CLIMATE NEUTRALITY BY UTILISING LARGE-SCALE OFFSHORE WIND

# INFRASTRUCTURE ELEMENTS AS ”BUILDING BLOCKS” FOR INTEGRATION OF OFFSHORE WIND

*Scenarios are investigated with different infrastructure configurations*

- AC grid connections to clusters at the coast
- HVDC grid connections to strong nodes in the electricity transmission grid
- HVDC interconnectors to neighboring countries
- Internal network reinforcements between regions with bottlenecks
- Deployment of hydrogen infrastructure in combination with electrolysis

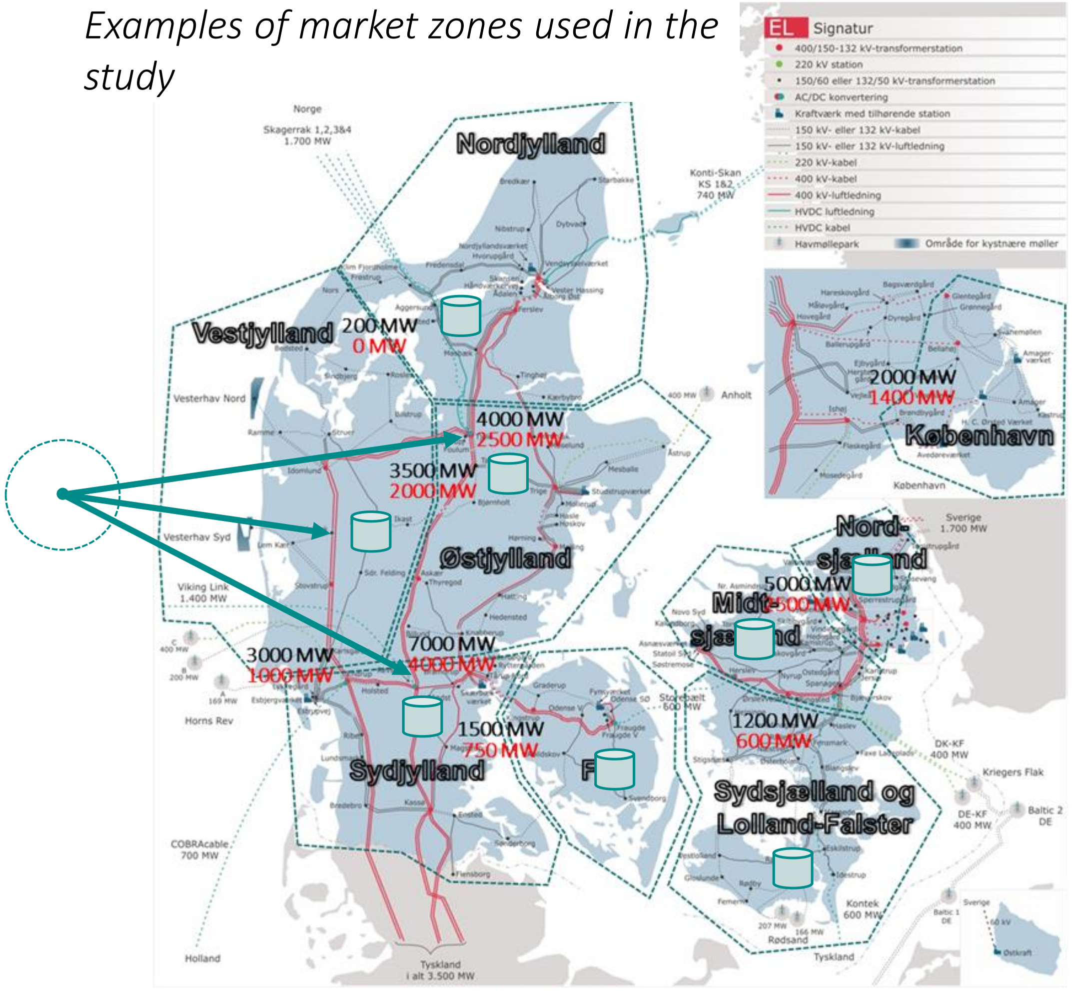


# GEOGRAHPIC MARKET ZONES AND FLEXIBILITY IMPROVES THE UTILISATION OF THE ELECTRICITY GRID

- Geographic market zones can strengthen:
  - Investment in (and operation of) flexible electricity demand (e.g. PtX plants) placed efficiently compared to the renewable electricity production.
  - Investment in and operation of batteries (or other storage options) to manage internal bottlenecks.
  - Local conversion of electricity to hydrogen and transport of the hydrogen in the gas system can reduce the need for electricity grid reinforcements.

- Flexible demand as grid reserve[1] requires development of the system operation and automatisation.
- New initiatives about geographic market zones and flexible electricity consumption as grid reserve can be combined with landing zones for wind (and solar).

*Examples of market zones used in the study*




Full grid capacity / grid capacity at n-1

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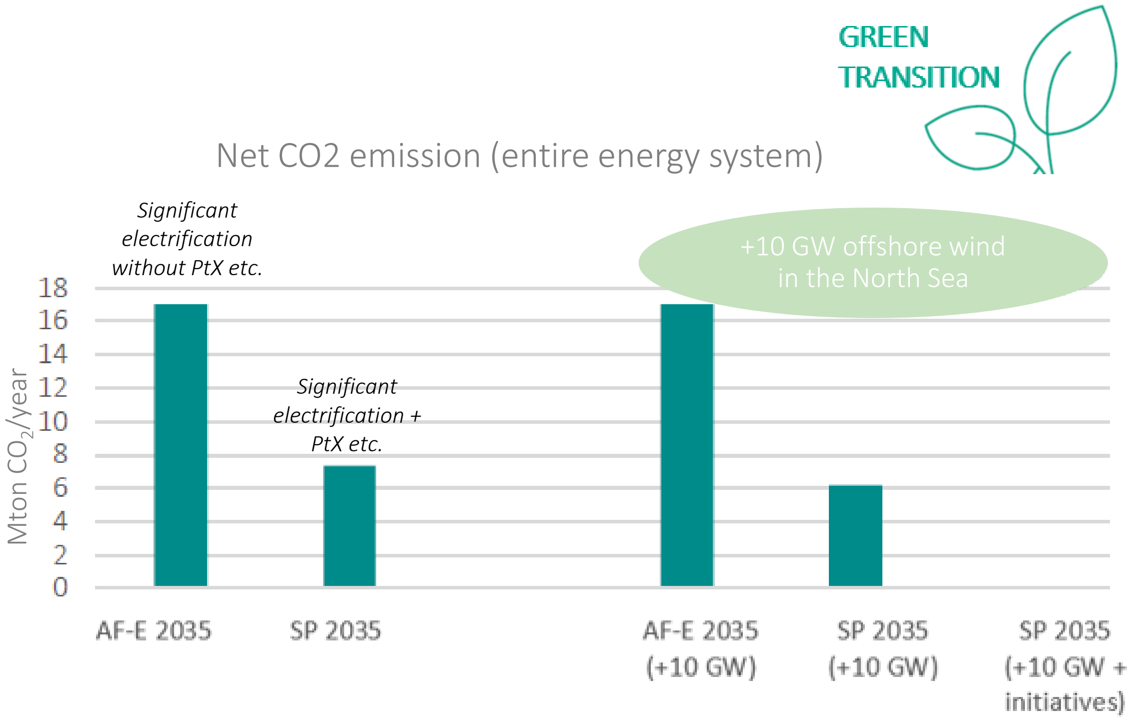
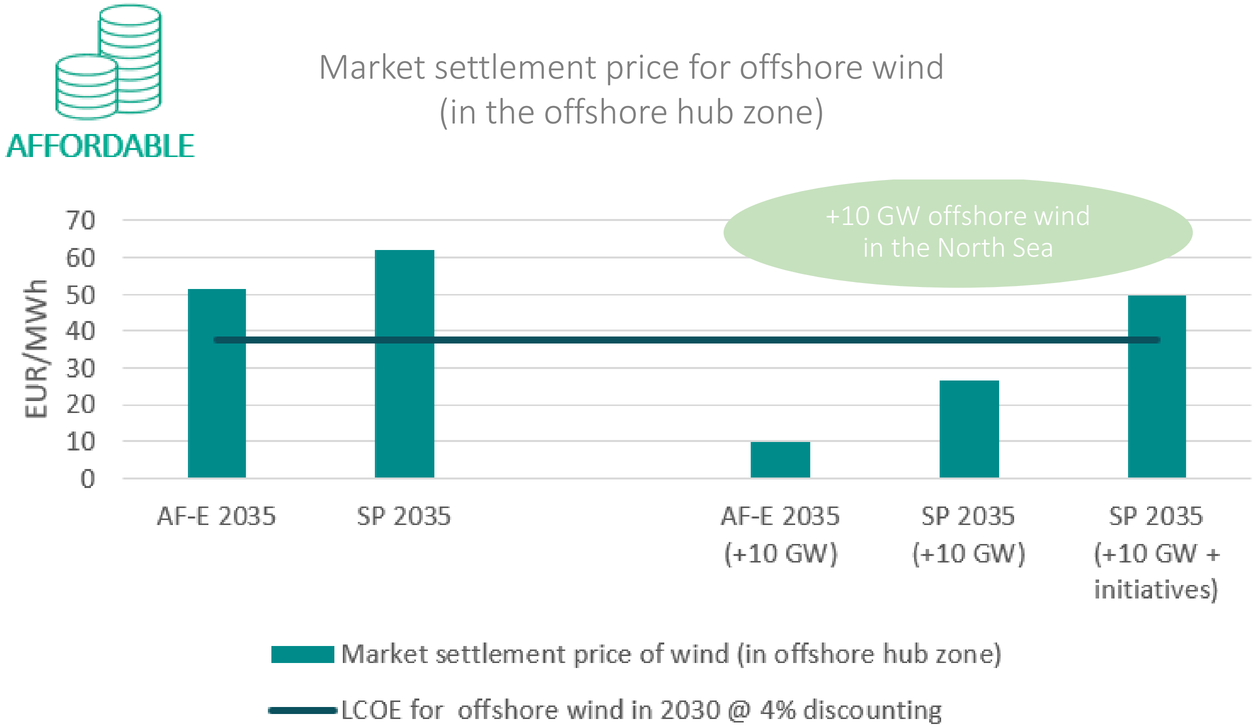
[1]*Reserved transmission capacity for reliefing in case of failures elsewhere in the transmission grid – a kind of "emergency lane". This service may in the future be provided by new sources of local flexibility e.g. electricity storages or electricity consumption.*

ENERGINET

# INFRASTRUCTURE INITIATIVES CAN INCREASE THE VALUE OF WIND POWER AND REDUCE THE NET $CO_2$ EMISSION




** The net CO2 emission is assumed as the RE-fuel that replace fossil fuels. It is also assumed that there is no import of RE-fuels.*
** Initiatives = hub with HVDC in-feed, hydrogen storage and pipes, increased deployment of PtX and close coupling of market and physics (the grid).*

# SECTION 3:
# SELECTED FOCUS AREAS

# INFRASTRUCTURE

- Offshore grid connection concepts
- Landing zones/energy clusters with sector coupling of electricity, gas, heat and liquified fuels
- Hydrogen infrastructure, hydrogen storage and $CO_2$ infrastructure

# MARKET

- Closer coupling of market and physics (grid)
- Flexible electricity demand as grid reserve
- TSO-DSO collaboration in market and bottleneck management

# SYSTEM OPERATION

- Automation of system operation including automatic activation of flexible demand
- Grid connection terms for new plants
- Dynamic Line Rating

# DIGITALISATION

- Linking data from plants and infrastructure with market and system operation
- Collection and display of data (Energy Data Service) to support decision-making
- Cyber security