Grønne Gasdage 2023

Biogas Danmark

GREEN GAS DENMARK

26. september

Rammer for PtX

11.10 Power to X-udbud, kickstart af industrien

Stine Sanderman Justesen
Teamleader, Energistyrelsen

11.40 Fundamentet for brinten

Rasmus Matthiessen
Manager of Regulatory Affairs, Ørsted

Biogas Danmark

GREEN GAS DENMARK

2023

Energistyrelsen

Power-to-X udbud-kickstart af industrien

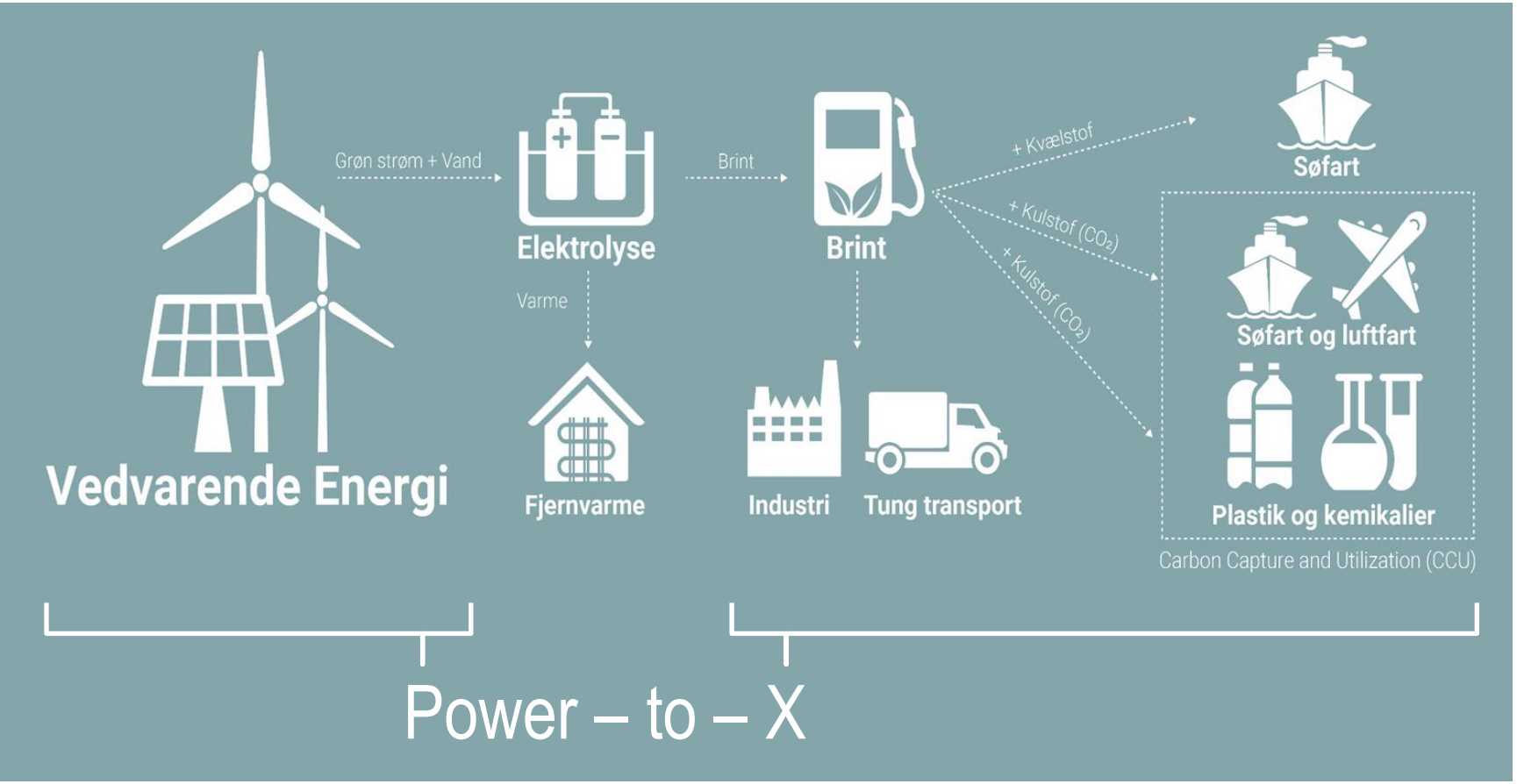
Stine Sandermann Justesen
Teamleder, Energistyrelsen

KICKSTART AF PTX INDUSTRIEN

- PtX-strategien – den politiske aftale
- PtX-udbuddet
- Regulering og krav til brug af PtX-brændstofferne

POWER-TO-X (PTX)

Produktion af grønne brændstoffer med udgangspunkt i brint via gennem elektrolyse



- Elektrolyse (produktion af brint) er kendt teknologi – begrænset udbredelse.
- Bruger meget energi og har "lav" effektivitet (~15 pct. spildvarme).
- Næste skridt er opskalering og industrialisering af anlæg og produktion.
- Nye teknologier på vej (PEM, SOEC) som er mere effektive men dyrere.
- Anlæg til viderekonvertering fra brint til brændstoffer er hovedsageligt kendte hyldevarer.

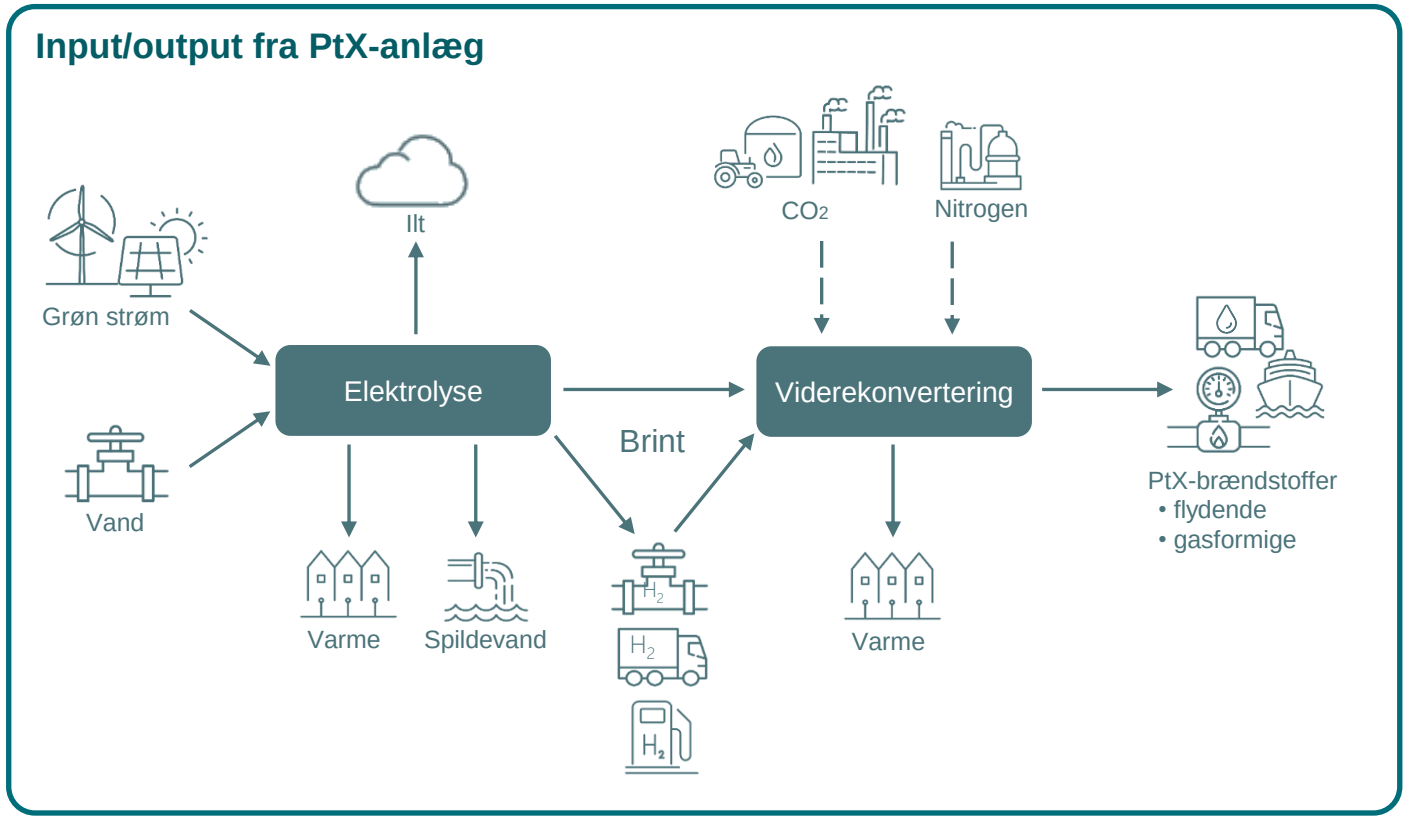
POWER-TO-X - INPUT/OUTPUT

Input

- PtX-anlæg bruger store mængder strøm og vand
- I viderekonvertering er der ofte behov for CO_2, fx fra biogasanlæg, affaldsbrænding mv.
  Transporteres med lastbil eller evt. rørledning.

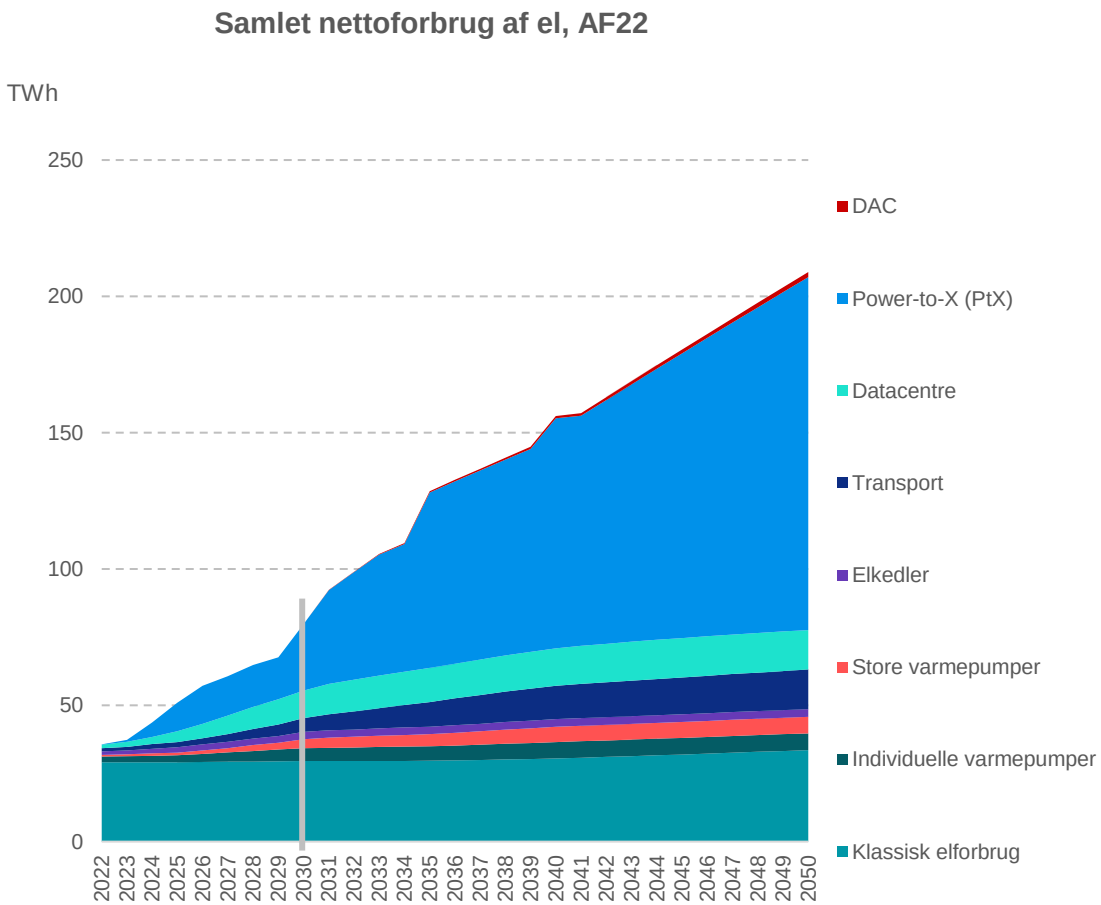
Output

- Brint transporteres til anvendelse eller til viderekonvertering – evt. lokalt.
- PtX-brændstoffer i flydende eller gasform transporteres med rørledning, lastbil eller skib.
- Spildevand fra rensning af vand til rensning eller udledning
- En andel af spildvarmen kan udnyttes til fx fjernvarme.



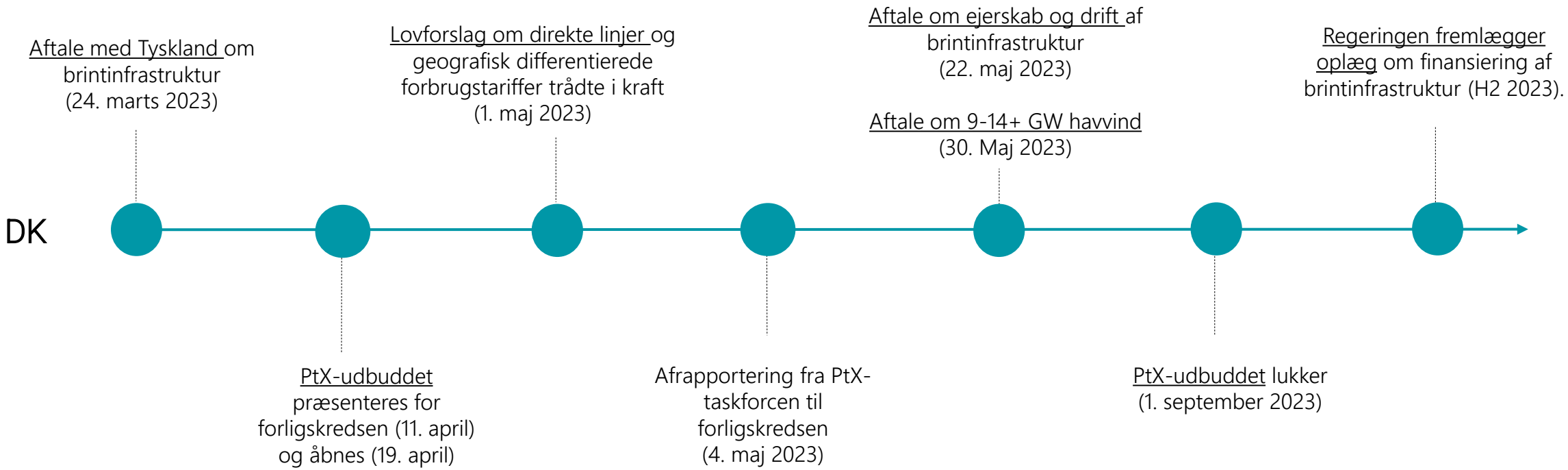
FORVENTNINGER TIL PTX-UDBYGNING I DANMARK PÅ SIGT

- Ambition i PtX-aftalen om etablering af 4-6 GW elektrolyse i 2030.
- Der ventes fortsat betydelig udbygning efter 2030, jf. AF22
- En betydelig andel af udbygningen efter 2030 ventes at ske på havet. Uklart hvor stor en andel.
- Øget udbygning af biogasanlæg for at understøtte uafhængighed og ambition om grøn gas i 2030
- På lang sigt forventes det, at CO_2 fra stort set alle biogasanlæg vil blive lagret eller anvendt til PtX.



Analyseforudsætninger til Energinet, Energistyrelsen, 2022

BRINT OG POWER-TO-X I 2023



EU

Brint- og gasmarkedspakke
Generel indstilling landet. Trilog-forhandlinger forventeligt i H2 2023.

EU's delegerede forordninger
Krav til grøn brint og PtX-brændstoffer. Trådte i kraft juli 2023

Aftagersiden
FuelEU færdig, VEIII-direktivet og ReFuelEU Aviation forventes færdigforhandlet efterår 2023

VIGTIGE TEMAER I TASKFORCENS ARBEJDE

De fem vigtigste områder for at fremme udrulningen af PtX i Danmark ifølge taskforcens Interessentforum

1. Adgang til billig grøn strøm
2. Klarhed om rammerne for brintinfrastruktur
3. Klarhed om tarifprodukter i elnettet
4. Understøttelse af markedstræk fra aftagersiden
5. Adgang til grøn CO_2 til produktion af PtX-brændstoffer.

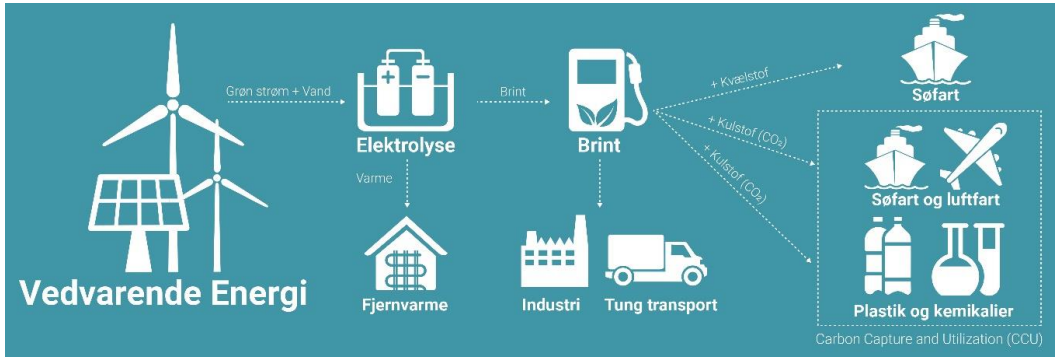
Seks udvalgte temaer for taskforcens arbejde det kommende år

1. Etablering af brintinfrastruktur
2. Strømligning på tværs af statslige og kommunale myndigheder
3. Levering og afledning af vand fra elektrolyse – *skal analyseres nærmere*
4. Fleksibilitet fra PtX-anlæg – *analyse forventes afsluttet før sommerferien*
5. Udnyttelse af overskudsvarme fra PtX – *skal analyseres*
6. Placering af PtX-anlæg
   Afklaring af mulighed for placering af PtX-anlæg på havnearealer, i det åbne land og på havet.

PTX-UDBUDDET - DEN POLITISKE RAMME

FORMÅL: At støtte og hjælpe industrialisering og opskalering af Power-to-X produktion i Danmark og dermed understøtte den grønne omstilling

- 1,25 mia. kr.
- Driftsstøtte til produktion af grøn brint over en 10-årig periode
- Markedsbaseret udbud, med henblik på billigst og størst brintproduktion
- Støtten baseres på et fast pristillæg
- Budlofter – generelt budloft samt et budgetstyrende budloft
- Vinderkriterie: Laveste bud på et pristillæg, indtil budgettet er tømt



PTX-UDBUDDET – VINDERKRITERIET

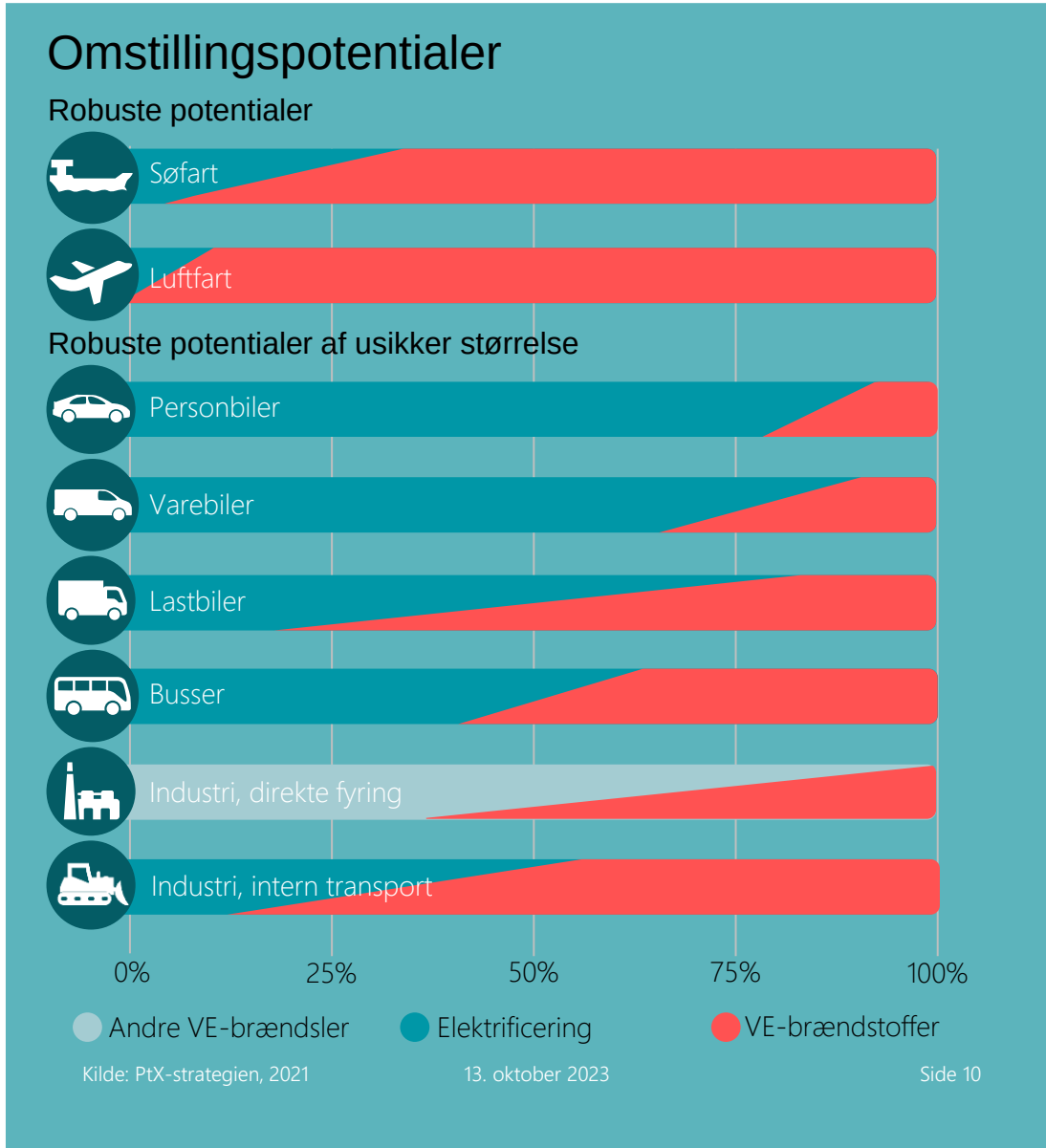
Laveste pristillæg DKK/GJ produceret grøn brint

- Den samlede mængde grøn brint produceret på 10 år der skal støttes
- Den fulde kapacitet for anlægget – bygges inden for 4 år efter kontrakt
- Støtten betales bagudrettet – på måneds basis
- Dvs. når dokumentation af brintproduktionen er indsendt, bliver støtten udregnet og derefter udbetalt
- Intet beløb forudbetales
- Ingen krav til anvendelse af brinten

HVOR SKAL VI BRUGE PTX-BRÆNDSTOFFER

PtX-brændstoffer skal anvendes, hvor elektrificering ikke er muligt

- PtX-brændstoffer er dyre og kan normalt ikke konkurrere med direkte elektrificering. Derfor skal vi elektrificere først.
- Visse segmenter kræver fortsat brændstoffer, fordi direkte elektrificering ikke er praktisk muligt.
- PtX-brændstoffer ventes at være billigere end biobrændstoffer på lang sigt og er derfor den mest omkostningseffektive vej til omstilling af nogle sektorer.
- Stor sikkerhed for efterspørgsel på PtX-brændstoffer i søfart og luftfart.
- Rimelig sikkerhed for efterspørgsel inden for tung vejtransport, dog mere usikker størrelse pga. konkurrence med elektrificering.
- Rimelig sikkerhed for efterspørgsel i industrien (højtemperatur og intern transport) og forsvaret samt til kemikalier og plastic.



Kilde: PtX-strategien, 2021

KRAV TIL BRUG AF PTX-BRÆNDSTOFFER - VEJTRANSPORT

Vedvarende Energi Direktivet, CO_2-fortrængningskrav

- EU CO_2 fortrængningskrav på 14,5% i 2030 (med nyt VE Direktiv)

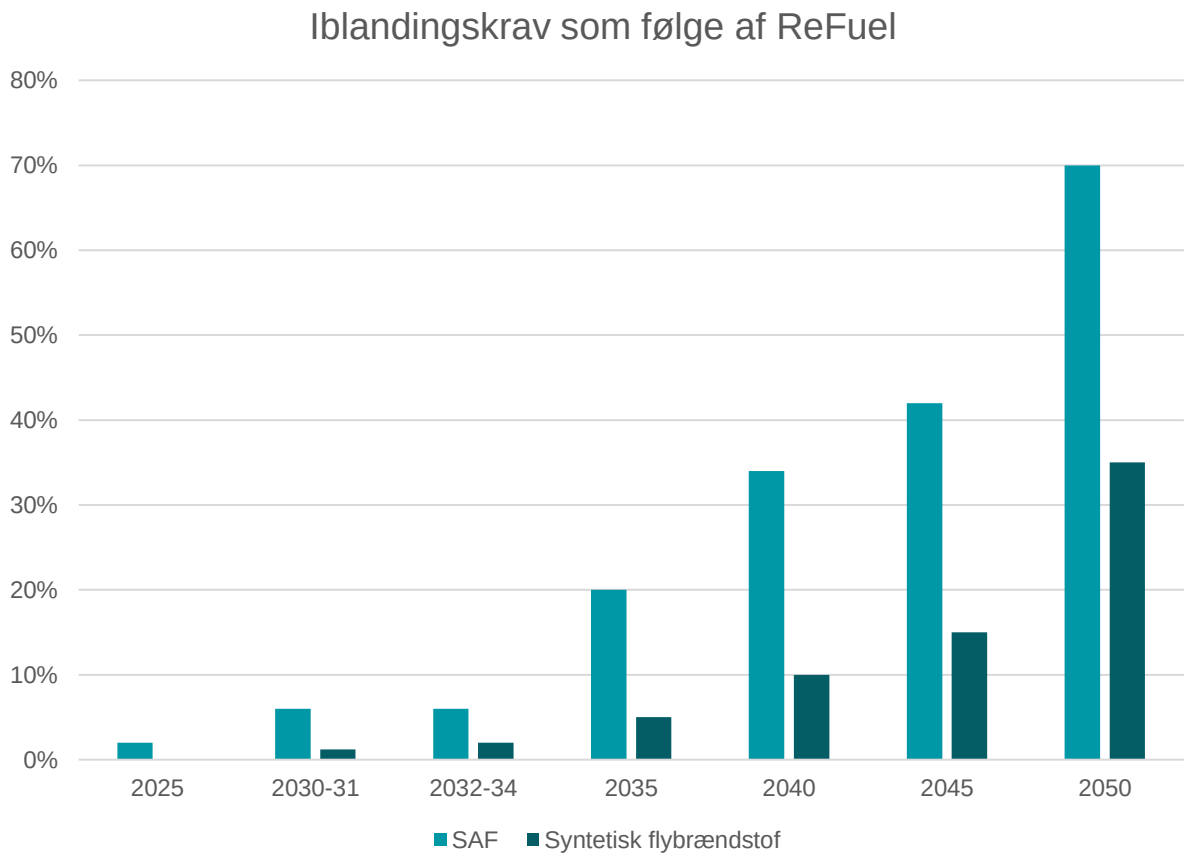
	VE II	VE III
Overordnet transportkrav i 2030	14 % iblandingskrav	29 % iblandingskrav eller 14,5 % CO2e-fortrængningskrav – MS bestemmer selv
Minimumskrav til avancerede biobrændstoffer – inklusive dobbelttælling, så de reelle tal er de halve	1 % i 2025 og 3,5 % i 2030	1 % i 2025 og 5,5 % i 2030. Kraven kan opfyldes med både avancerede biobrændstoffer/gas og RFNBO
Minimumskrav til RFNBO	Ingen	1 % i 2030
Tvungen iblanding af RFNBO i søfarten	Ingen	1,2 % i 2030

KRAV TIL BRUG AF PTX-BRÆNDSTOFFER - LUFTFART

ReFuelAviation

Iblandingskrav til grønne flybrændstoffer

- Sustainable Aviation Fuels (SAF), defineres som flydende VE-brændstoffer, som både er biogene og syntetiske.
- Førstegenerations biobrændstof, som er biobrændstof baseret på afgrøder som dyrkes med det primære formål at producere brændstof, vil ikke kunne anvendes
- Specifikt underkrav for syntetiske flybrændstoffer (som kan baseres på både VE og kernekraft).
- Iblandingskravet for syntetiske flybrændstoffer er pålagt en række undtagelser. Således er 2034 første år med krav til brug syntetiske flybrændstoffer.
- I perioden 2025-34 vægtet gennemsnit på tværs af alle EU-lufthavne.



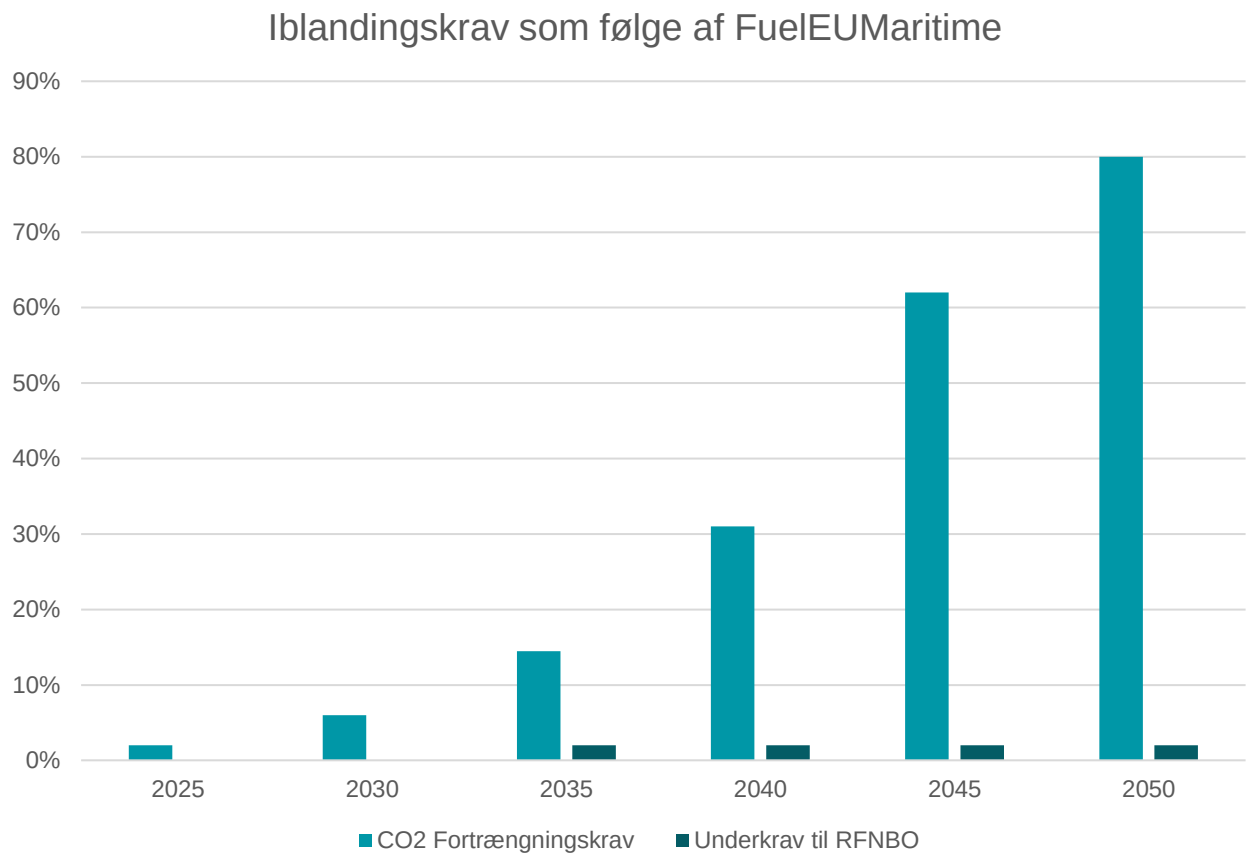
KRAV TIL BRUG AF PTX-BRÆNDSTOFFER - SØFART

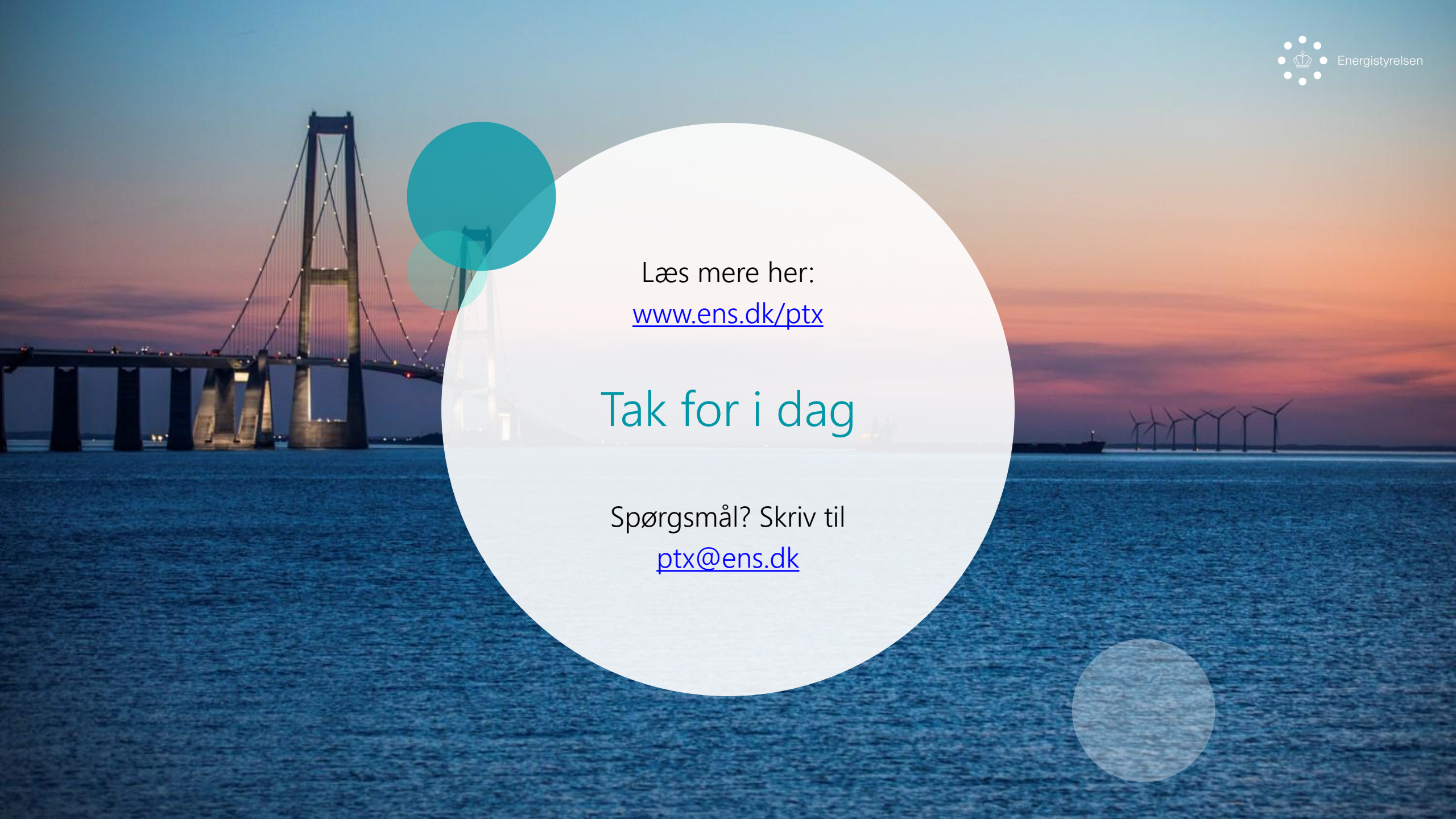
FuelEUMaritime

CO_2-fortrængningskrav

Biobrændstoffer baseret på fødevarer og foder kan ikke tælles med

Krav om brug af landstrøm i havne





Energistyrelsen

Læs mere her:

www.ens.dk/ptx

Tak for i dag

Spørgsmål? Skriv til

ptx@ens.dk

Næste oplæg

Rasmus Matthiesen,
Ørsted

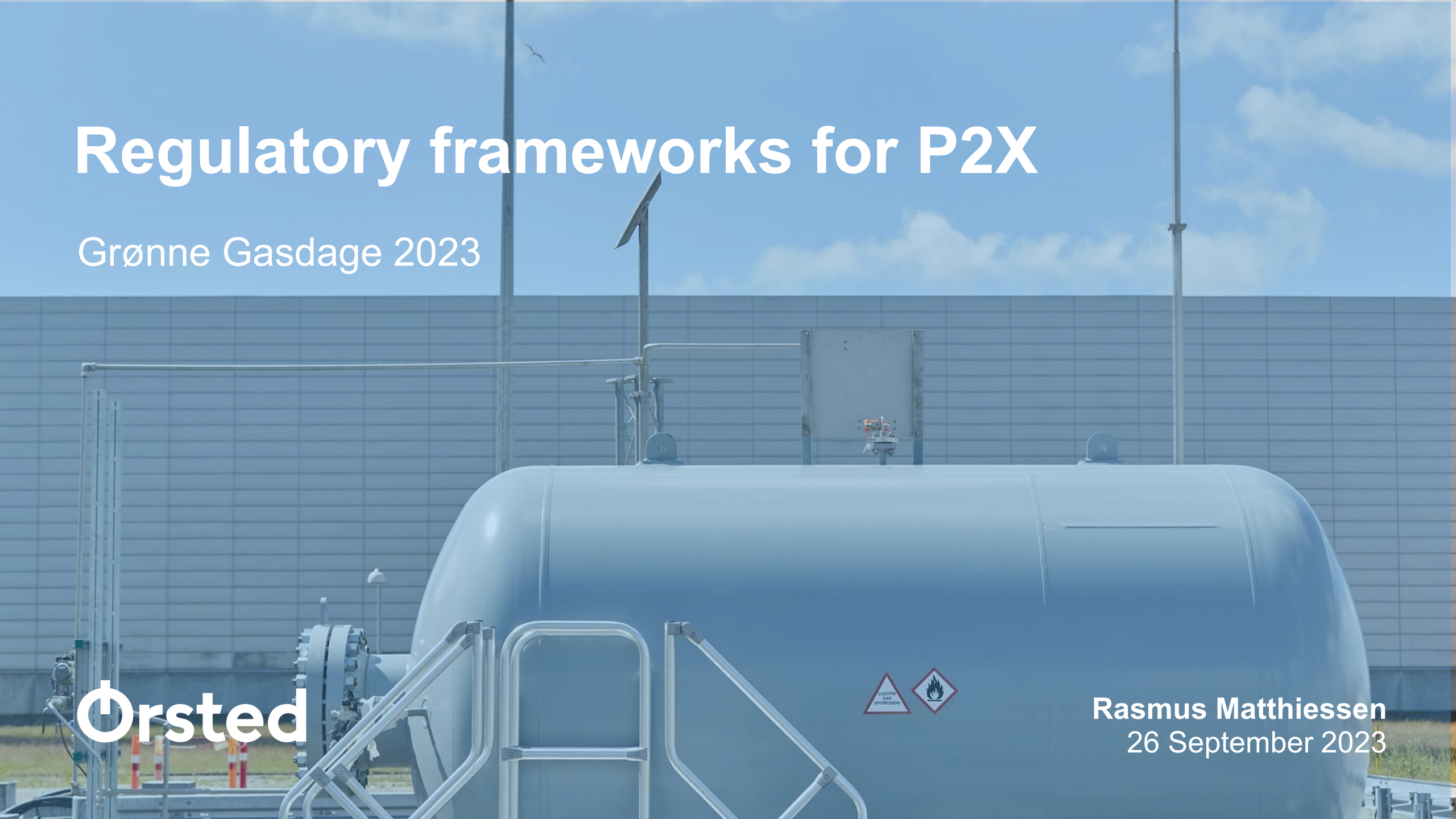
Biogas Danmark

GREEN GAS DENMARK

2023

Regulatory frameworks for P2X

Grønne Gasdage 2023



Ørsted

Rasmus Matthiessen

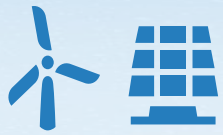
26 September 2023

To reach net-zero, the world requires Power-to-X solutions

Many sectors can be decarbonised with green electricity, but

~30 %

of global emissions come from **hard-to-electrify** sectors, which need different solutions



Power
Renewable energy generation

to
powers the production of

X
renewable hydrogen and e-fuels

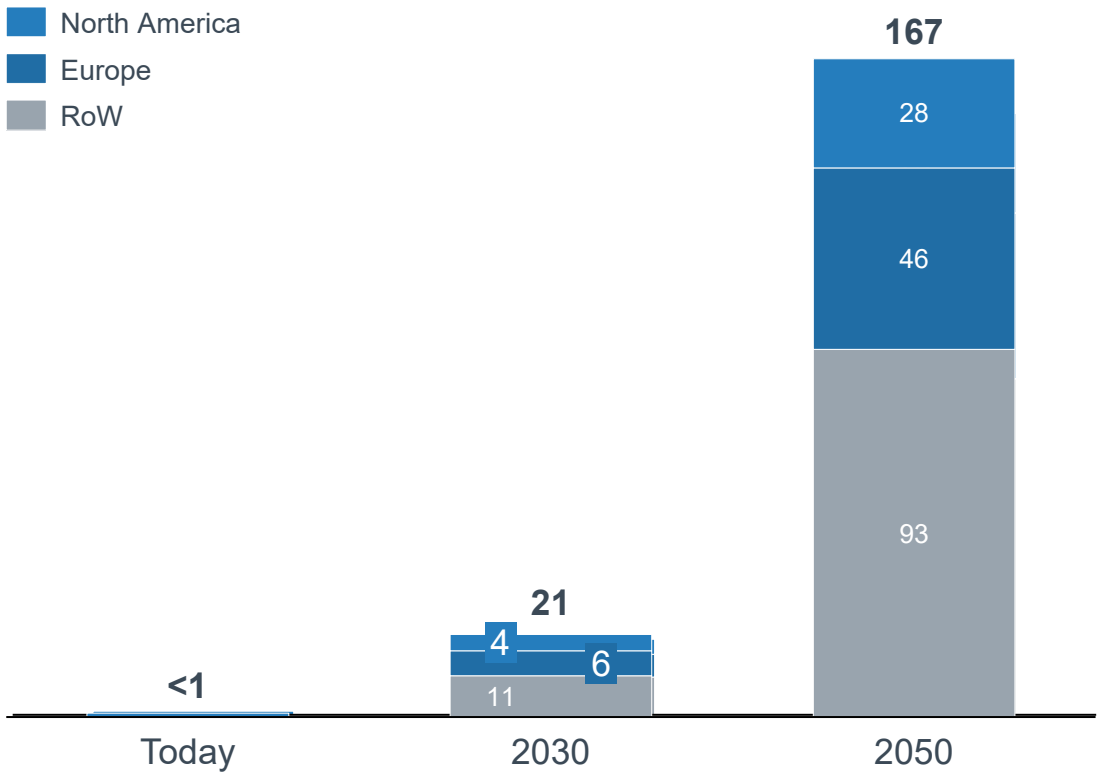
Direct hydrogen	E-fuels		
	E-methanol	E-ammonia	E-kerosene
Steel	Chemicals	Chemicals	Aviation
Refining	Maritime	Maritime	
Transport	Input to jet fuel	Fertilisers	

Source: Energy Transitions Commission (2018).

Exponential P2X growth outlook with clear market signals

Exponential demand growth for global renewable H_2

Renewable hydrogen demand mtpa H_2 equivalent[1]



Promising signals for tangible market growth

Strong regulatory signals

Demand and supply side support, delivered by the US & Europe, signals increasing support and catalyses sector maturation[2]

Forward-leaning demand sectors

Tangible demand is developing from sectors, such as the steel and maritime industries

Emerging pockets of value now

'First phase' projects can realise both financial returns and concrete learnings

Enabling infrastructure build out

Necessary hydrogen backbone build-out by TSOs[3] in Europe and hydrogen hub development in the US

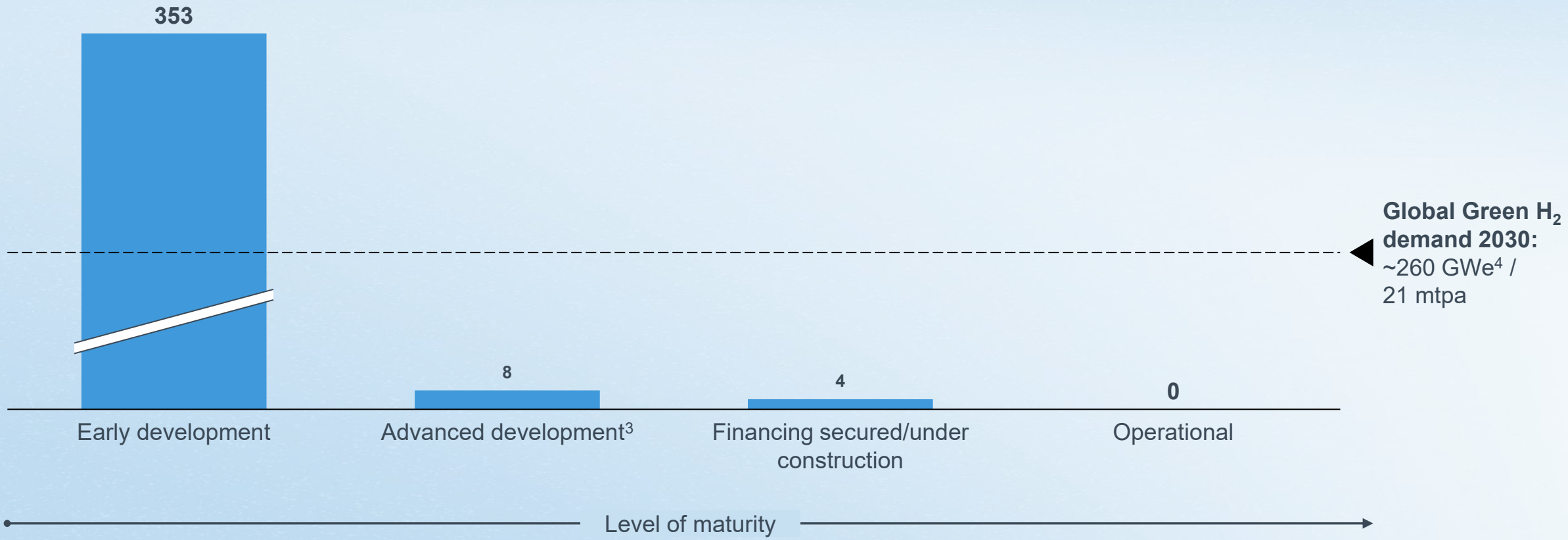
Notes: 1. Based on IEA's Announced Pledges Scenario (APS) H_2 balance overview, as of September 2022. Regional demand split percentage applied from internal forecast to IEA data. 2. Incl. 20 million tonnes RePowerEU target, EUR 3 billion supporting 820 MW through the European Hydrogen Bank, EUR 10.6 billion, Inflation Reduction Act (IRA) subsidisation up to USD 3/kg H_2 production tax credit (the US), H2Hubs funding of USD >14 billion (the US). 3. Transmission System Operator (TSO).
Sources: IEA (2022), GlobalData, Nexant.

Ørsted

Many P2X assets struggle to reach maturity

Total global green H_2 announced pipeline by status[1] (excluding China[2])

GWe

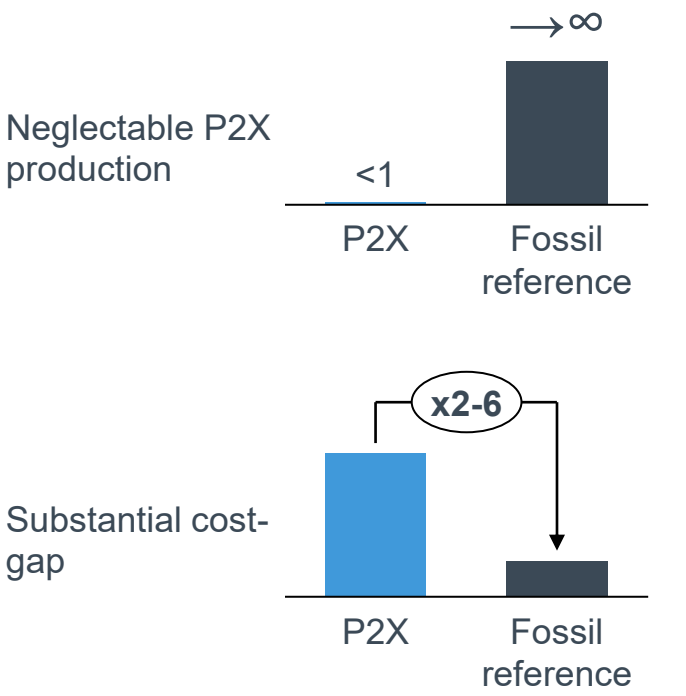


Notes: 1. Estimates based on publicly available information. 2. Announced project pipeline in China amounts to 45 GWe, with 2 GWe operational. 3. Advanced planning consists of projects with "Permits obtained" according to BNEF categorization. 4. Estimated electrolyser capacity required to meet forecasted renewable H_2 demand of 21 mtpa, based on IEA's Announced Pledges Scenario (APS) H_2 balance. Demand includes China.
Sources: BNEF (2023), IEA (2022), Ørsted analysis.

Ørsted

Why legislation and funding is essential

Cost and volume gap



No P2X market today on fully commercial terms

Policy levers

		Examples
Ambitions & targets	Decarbonization objectives	Paris agreement, national GHG reduction targets
	Offtake-side quotas	EU industry and transportation targets for renewable P2X (REDIII, FuelEU, RefuelEU)
	Production-side targets	DK 4-6GW and DE 10GW ELY targets for 2030
Market enablers	Definitions of H2 types	EU Delegated acts to REDII, US Clean Hydrogen Production Standard (DOE)
	Certificates and markets	EU Union-database, EU Certify, US Renewable Energy Certificates ("RECs"), ASTM standards.
	Co-location and infrastructure	EU backbone, Landing zones, US H2 Hubs, US Hydrogen Infrastructure (permitting reform)
Cost-gap fillers	Carbon pricing	EU ETS scheme, CBAM
	Tax reductions	IRA, EU Energy Taxation Directive
	Direct funding	EUIF, IPCEI, EU H2 Bank

Ørsted

Three main market barriers for the ramp-up of renewable P2X in Denmark

1

Renewable electricity

Access to affordable green electrons is currently the biggest barrier in bringing P2X projects on the ground

2

Infrastructure

P2X will only succeed if exporting renewable hydrogen is enabled through planned H_2 infrastructure

3

Regulation & incentives

Newly adopted regulation in EU and DK is essential to help kick-start the industry. However, new regulatory frameworks needed to enable large-scale ramp-up

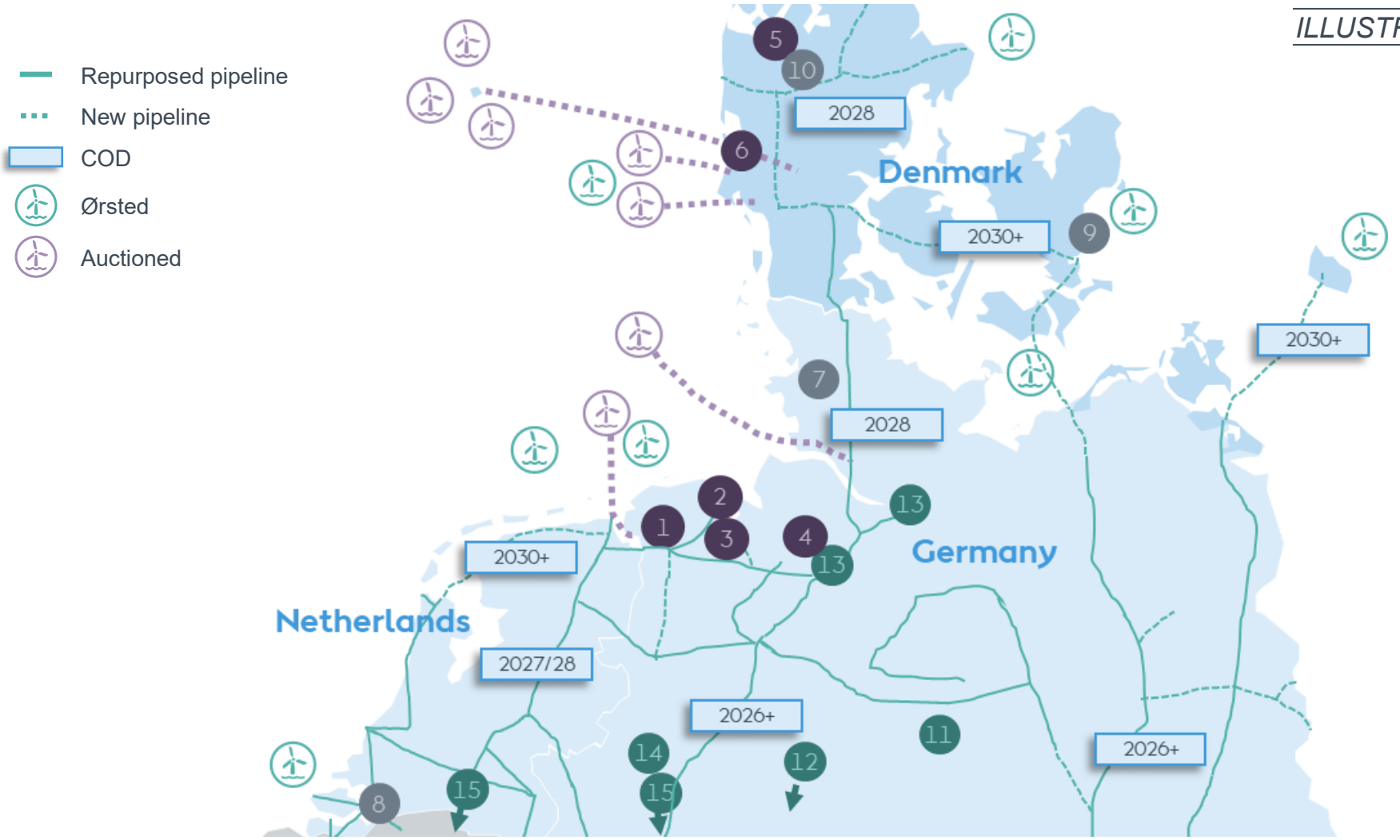
Development of planned H_2 infrastructure is key to realize P2X build-out and connect to large-scale demand centres in due time

ILLUSTRATIVE

Potential H_2 hubs
1. Emden
2. Wilhelmshaven
3. Brake
4. Farge
5. Idomlund
6. Esbjerg

Ørsted H_2 projects
7. WK100
8. SeaH2Land
9. GFDK
10. Idomlund

Industrial sites
11. Salzgitter
12. Dillinger
13. Arcelor Mittal
14. Thyssenkrupp
15. BASF



Source: European Hydrogen Backbone.

Ørsted

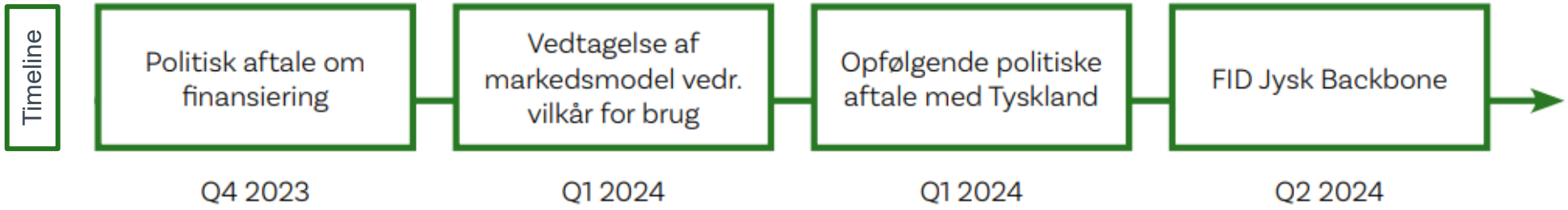
Anbefalinger til finansiering af dansk brintinfrastruktur

Anbefalinger

Anbefaling I:	**Statsgaranti**
Anbefaling II:	**Fleksible rammevilkår**
Anbefaling III:	**Dansk-tysk aftale**
Anbefaling IV:	**Fremtidssikring**
Anbefaling V:	**Mulig statsstøtte**

Afsendere

Brintbranchen, Hydrogen Valley, Dansk Erhverv, Dansk Industri, Green Power Denmark, RWE, String, CIP Copenhagen Infrastructure Partners, Crossbridge Energy Partners, Vattenfall, Everfuel, Eurowind Energy, greengo energy, plug, GreenLab, H2energy, Skovgaard Energy, NH2 Danmark, TotalEnergies, Ørsted



Source: Anbefalinger kan findes på DIs hjemmeside.

Ørsted

Significant economic value creation expected from growing Danish P2X buildout

Large-scale value creation with positive outlook

DKK 30-75 bn net social benefits towards 2060, from the H_2 pipeline Jutland to Germany

Energinet study 2023

DKK 4-33 bn export value in 2030, by capturing 15-20% of the EU's estimated capacity[1]

Brintbranchen study 2022

Value creation supported by multiple channels

- Job creation
- Income taxes
- Taxes on export revenues
- Congestions rents
- Sale of offshore wind sites

Notes: 1. Based on EU estimates of reaching 40 GW electrolyser capacity by 2030.
Sources: Energinet (2023), Brintbranchen (2022).

Q&A

Thank you

Frokostpause til kl. 13.10

Frokost i Multihuset

Mulighed for at besøge udstillingsboderne

Biogas Danmark

GREEN GAS DENMARK

2023

Modning af PtX

13.10 PtX – Skalering og modenhed

Thomas Hagelund
COO, Green Lab Skive

13.40 PtX – Sikker opskalering, med certifikater og standardisering

Peter Paschke
Senior Pincipal Surveyor, DNV

Biogas Danmark

GREEN GAS DENMARK

2023

Grøn og cirkulær industriklynge – Teknologi-katalysator – Nationalt forskningscenter

Thomas Hagelund Helsgaun, COO – GreenLab A/S, Skive, Denmark
THEL@GreenLab.dk

Grøn og cirkulær energipark

- En fysisk platform, hvor man kan "sparke dæk"
- Forsynet med 100% vedvarende energi: 80 MW vind- og solenergi, genereret on-site og med nettilslutning
- Sektorkobling i praksis: Industri koblet med PtX og til omverden via SymbiosisNet™ - et intelligent netværk af energi og data

Teknologi-katalysator

- "Den perfekte vært" for teknologi-virksomheder. Vi leverer infrastruktur og services, der forkorter time-to-market
- Vi introducerer hønen til ægget og nye markeder opstår
- Facilitator for grøn omstilling

Nationalt forskningscenter

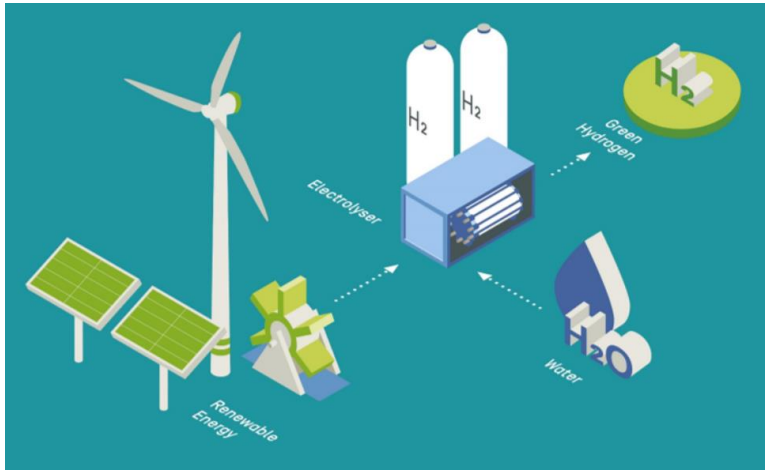
- Videnscenter for intelligent, integreret energi
- Accelererer R&D til kommerciel skala
- Uddannelse og kompetenceudvikling af fremtidens arbejdskraft

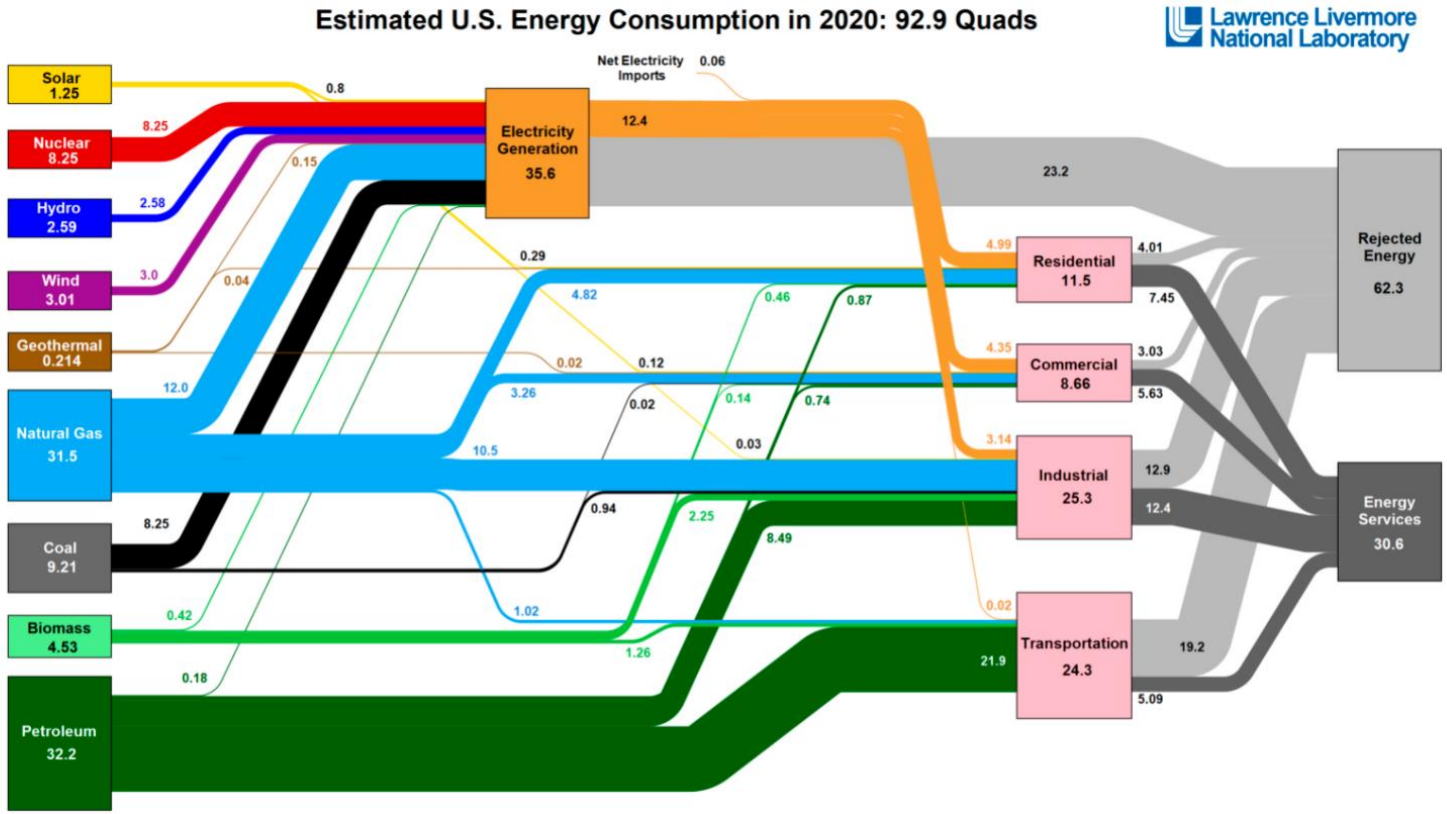
PROPERTY OF GreenLab

Hvorfor industrisymbiose?

Hvilket problem forsøger vi at løse?

- Ca. 2/3 af verdens energiproduktion går tabt pga. energitab
- Ca. halvdelen af energien i industrien går til spilde
- Lagring af vedvarende energi kan potentielt medvirke til endnu mere energitab (varme)





GreenLab

GENERATE

Vi genererer vedvarende energi

STORE

Den vedvarende energi bliver konverteret og lagret i alle former: El, varme, gas, brændstoffer

SHARE

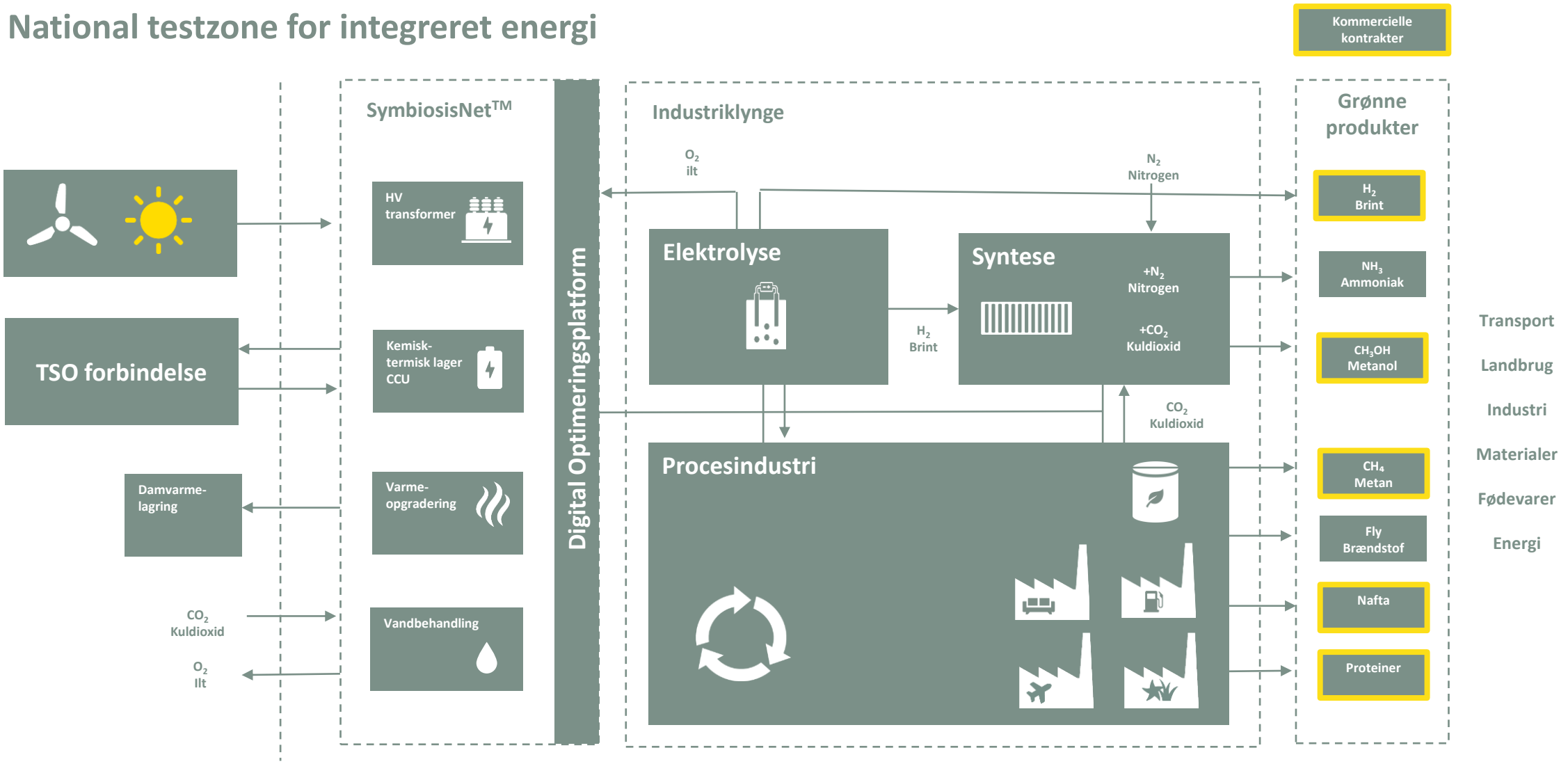
Via SymbiosisNet™ bliver energien omfordelt mellem parterne

GreenLab

Located at the intersection of national gas and electricity grids

GreenLab Skive industriklynge – SymbiosisNet™

National testzone for integreret energi



GreenLab Skive energipark

Samarbejde med DSO/TSO

- System fleksibilitets-ydelser
- Virtual Direct Connection
- Granular Certificates of Origin
- Sektorkobling

Regulatorisk testzone og lokal kollektiv tariffering


ENERGY WATCH

Utilities Oil & Gas Renewables Cleantech Policy & Trading Danish

Danish government indicates regulatory test zones exempt from law

Siemens Gamesa and Greenlab Skive receive dispensation from Danish power supply legislation and thereby an opportunity to test new technologies. An important step toward ensuring a PtX head-start for Denmark, says the turbine maker.

Further reading

SSE Renewables appoints new managing director


Startside Din virksomhed Om Indlæg Job

GreenLab
10.427 følgere
4t •

Lad den grønne energi flyde! Ny lovændring gør det nemmere at udnytte lokale sol- og vindressourcer i regulative testzoner som GreenLab.

Vi er glade for at Folketinget i går vedtog en vigtig ændring af elforsyningsloven, som muliggør lokal, kollektiv tarifering. Det betyder, at GreenLab og andre regulative testzoner i Danmark får lov til permanent at beholde de fordelagtige vilkår, som en midlertidig testzonetilladelse giver.
Det gør os i stand til at udnytte lokalt produceret grøn strøm på den mest optimale måde.

Fra i dag er der dermed skabt *nye* rammer for både tariferings- og afregningsmodeller og det gør det muligt at teste endnu flere innovative og grønne forretnings- og energimodeller af i praksis.

Der er blevet arbejdet benhårdt af partnere og medlemmer i klima-, energi- og forsyningsudvalget, og vi har været glade for en åben og effektiv dialog med politikerne. Vi vil gerne sige et særligt tak til Signe Munk og Anne Paulin, som har gjort en særlig stor indsats for a realisere ændringen af elforsyningsloven.

Derudover er vi utrolig stolte af, at GreenLab er nævnt som et eksempel direkte i betænkningen. Læs med her: https://lnkd.in/eKTXTvgn

#letscreateapowershift #greentransitioninaction #elforsyningsloven

Today is a great day for the green transition! The national transmission company Energinet and GreenLab have agreed to establish a Learning Lab to test new energy and supply solutions exploiting GreenLab's unique test zone cluster environment.

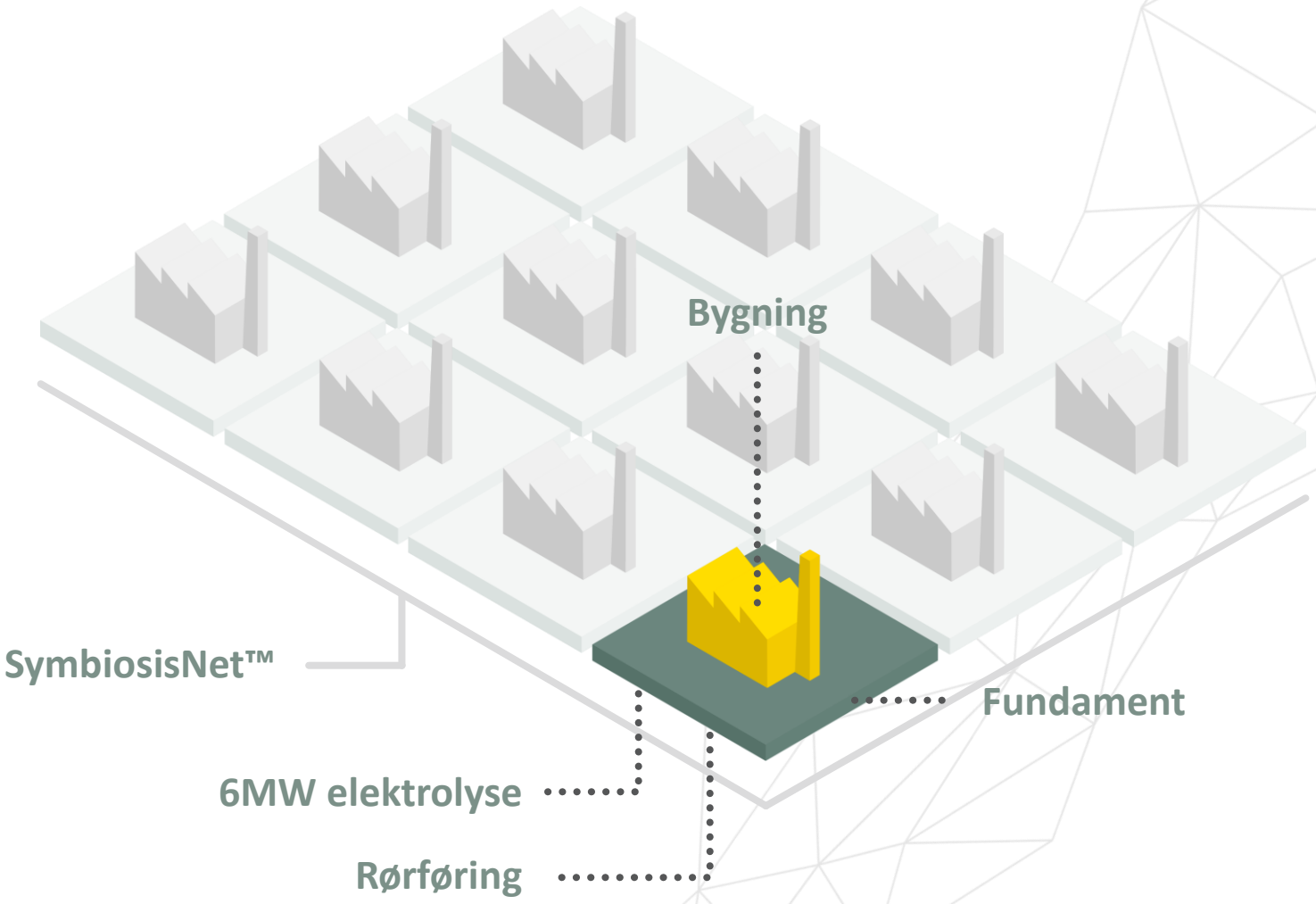
We will explore new solutions to accelerate sector integration, system flexibility, and data-driven systems and we will challenge the current market models to determine mutual incentives and high social impact for Denmark's green transition

Source: Management information.

Facility-as-a-Service

En plug-and-play PtX platform

- Et unikt værtsmiljø - komplet infrastruktur til grønne virksomheder
- Open innovation platform med adgang til grøn strøm og vores SymbiosisNet™
- Kortere time-to-market



PROPERTY OF GreenLab

”GreenLab Skive P2X” projekt

12 MW i Q1 2023 – 10 mio. EUR bevilling

Primære formål

At demonstrere og udvikle hele værdikæden i et effektivt samspil mellem kendte teknologier (vind, sol, infrastruktur, lagring, brint, biogas, metanol) til værdifastsættelse og markedsføring af grønne brændsler, både onsite og offsite. Projektet bidrager til at løse energilagringsproblematikken i fremtidens elnet.

Danmarks Tekniske Universitet DTU

Everfuel

EUROPEAN ENERGY

e·on

ENERGINET

NORLYS

GREEN HYDROGEN SYSTEMS

DGC Dansk Gasteknisk Center a/s

Eurowind Energy

Ea Energy Analyses

Energistyrelsen

PROPERTY OF GreenLab

THIS PROJECT HAS RECEIVED FUNDING FROM THE EUROPEAN UNION'S HORIZON 2020 RESEARCH AND INNOVATION PROGRAMME UNDER GRANT AGREEMENT NO 101036935

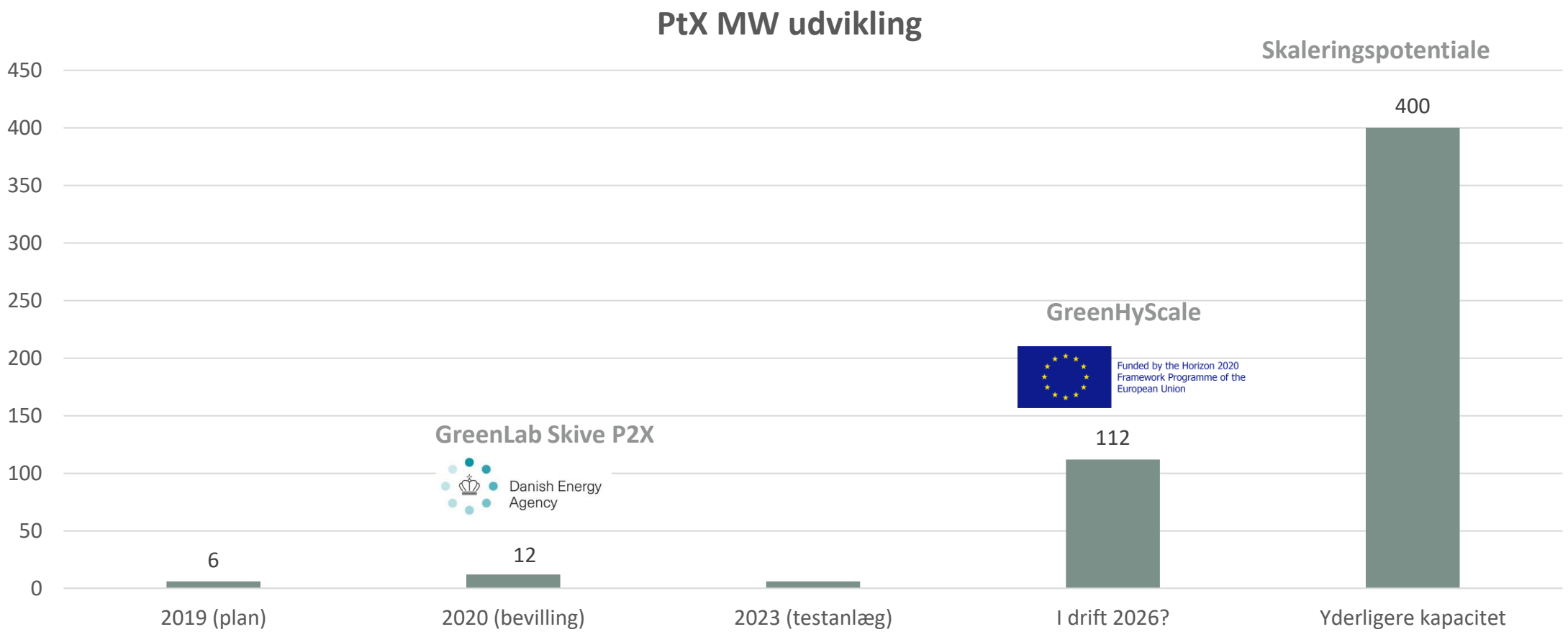
GreenHyScale projektet

Verdens største elektrolysesystem der er kvalificeret som en TSO-balancerende serviceudbyder

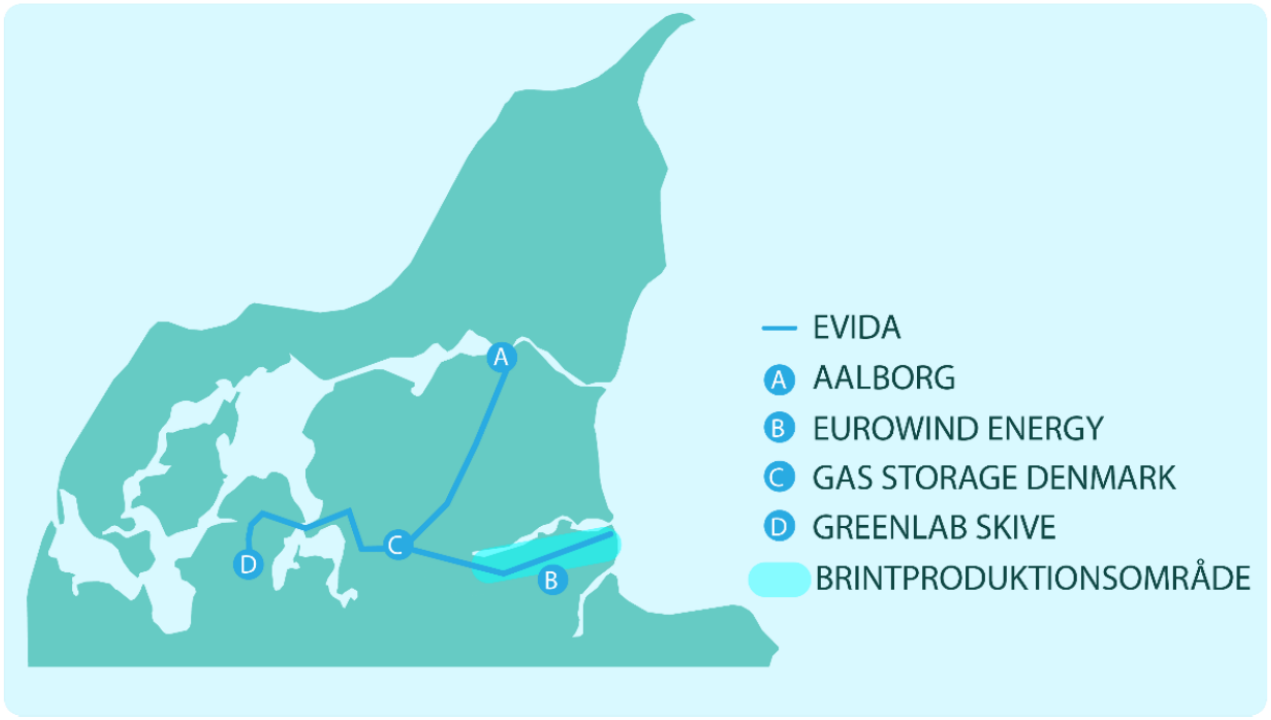
- Primært formål: At bane vejen for storskala udvikling af elektrolyse onshore og offshore
- Skabe ny multi-MW alkalisk elektrolyseplatform
- Skabe et 6MW modul der kan passes ind i en 40-fods container
- Producere grøn brint i to år via 80MW direkte forbundet vedvarende energi og certificeret elektricitet fra en TSO netforbindelse
- GreenLab distribuerer elektriciteten via sit SymbiosisNet™

PROPERTY OF GreenLab

GreenLab Skive PtX udviklingskurve



Nyt økosystem, brintinfrastruktur / ClusterNorthH2

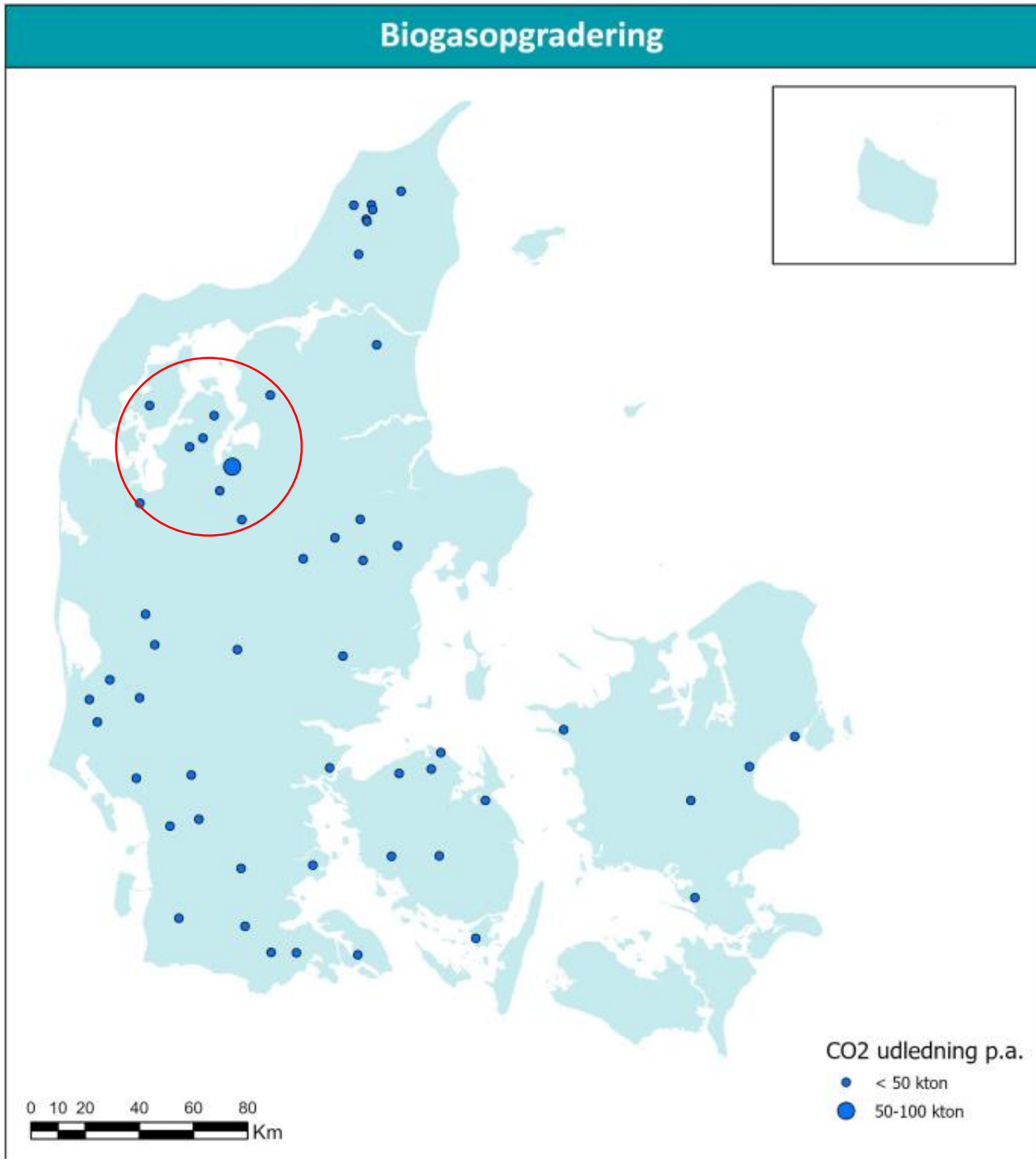


Figur 1: Oversigt over ClusterNorthH_2 projektet

Lokalt CO2-potentiale fra biogas opgradering

Ca. 160.000 ton/året

Tracé og anlæg af rørledning

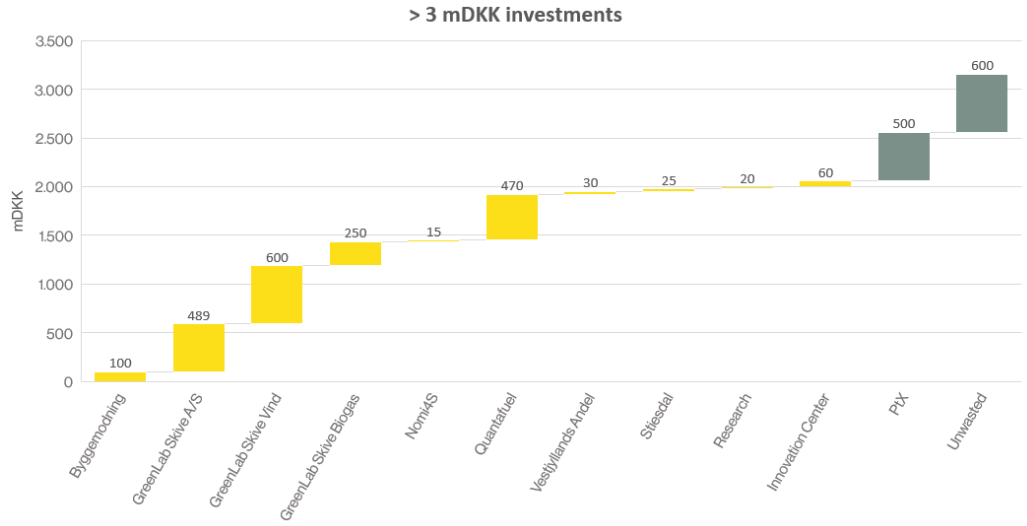


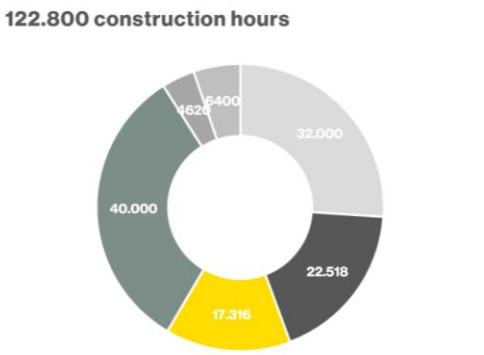
Udfordringer med PtX

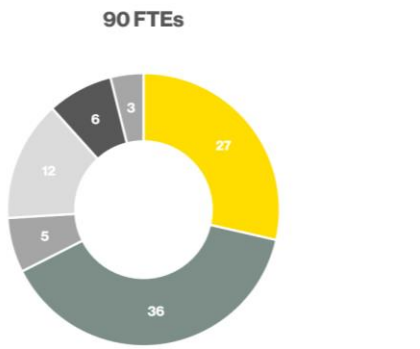
- Betydeligt gap mellem Levelized Cost of Hydrogen (LCoH) og marked
  - Vil kræve massiv statsstøtte! Subsidier, CO2 afgifter og brintinfrastruktur at få markedet i gang - og nå til FID
  - Værdikæder skal modnes og støttes - det fokuserer vi på
- Vi navigerer alle sammen det ukendte – ingen er eksperter på PtX endnu…
  - GreenLab tror på at man skal se PtX i en større sammenhæng - integreret med industriklynger og i et sammenhængende energisystem.
- Det er en kæmpestor ligning der skal løses:
  - Alene Maersk's 2030 methanol behov (5 mio. tons/år) vil kræve 20GW VE og 37,500 lastbiler om dagen til transport af gylle alene ind og ud af GreenLab
  - En fuldt udbygget GreenLab med 80MW VE, 24MW elektrolyse og 20,000 tons methanol **X 250**
- PtX alene kommer ikke til at løse klimakrisen – der skal også ses på alternativer, og ikke mindst forbrug (hvilket problem forsøger vi at løse?)
  - Samplacering af produktion og forbrug – grøn vækst, retfærdig grøn omstilling

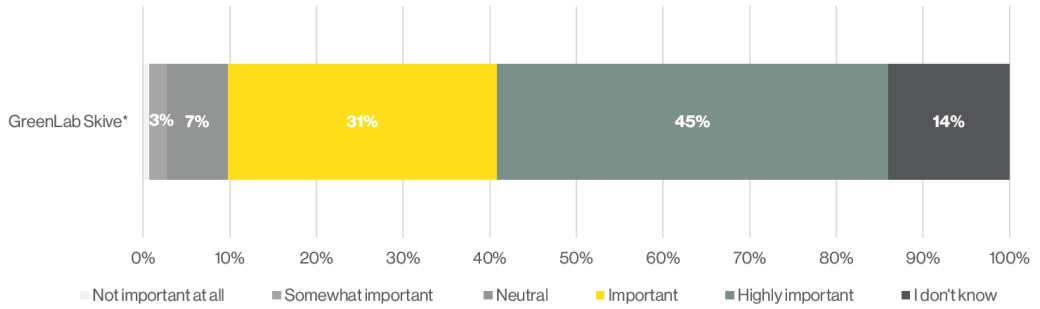
Social Impact

Investments, green jobs, business tourism, local engagement









"To which extent do you view the following as important to the development of the Skive area?"

PROPERTY OF GreenLab


LET’S CREATE
A POWER SHIFT
PROPERTY OF GreenLab

Næste oplæg

Peter Paschke,
DNV

Biogas Danmark

GREEN GAS DENMARK

2023

WHEN TRUST MATTERS

Sikker opskalering, med certifikater og standardisering

Grønne Gasdage 2023

Peter Paschke

26 September 2023

Our purpose

To safeguard life, property, and the environment

Our vision

A trusted voice to tackle global transformations

01 Introduction

02 CO_2 & Hydrogen safety properties

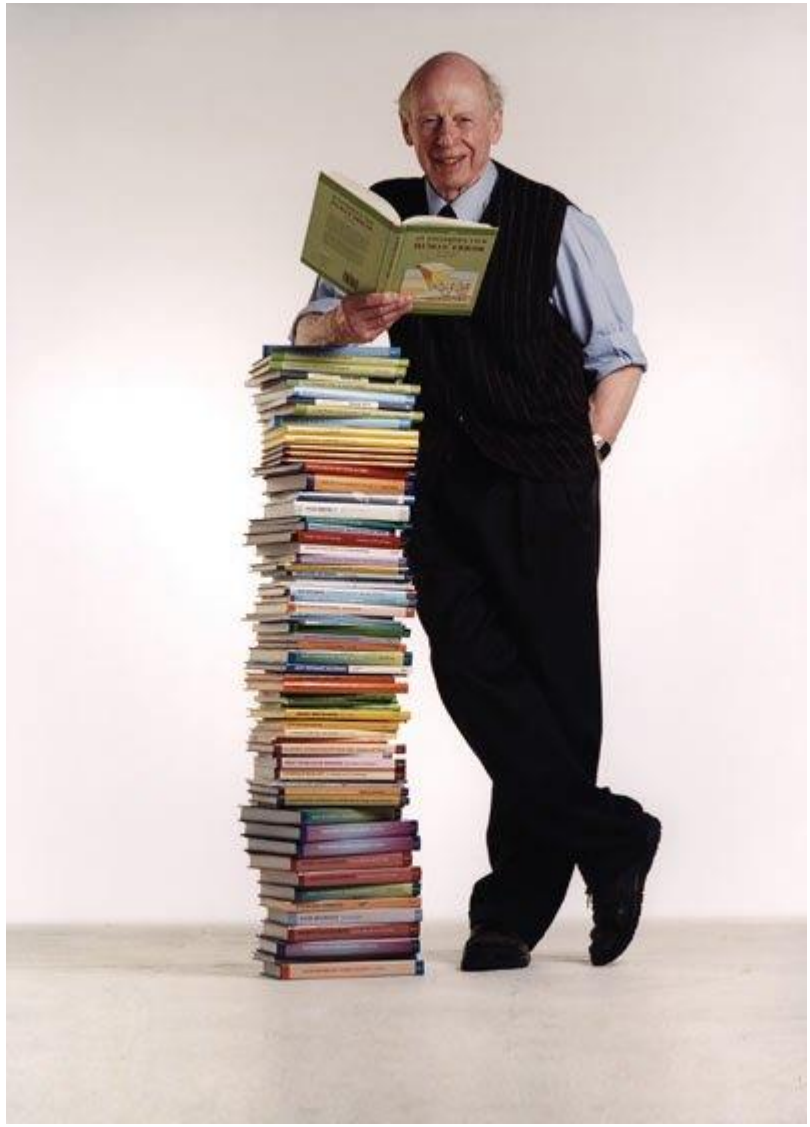
03 Manage safe upscaling

04 Standardisation

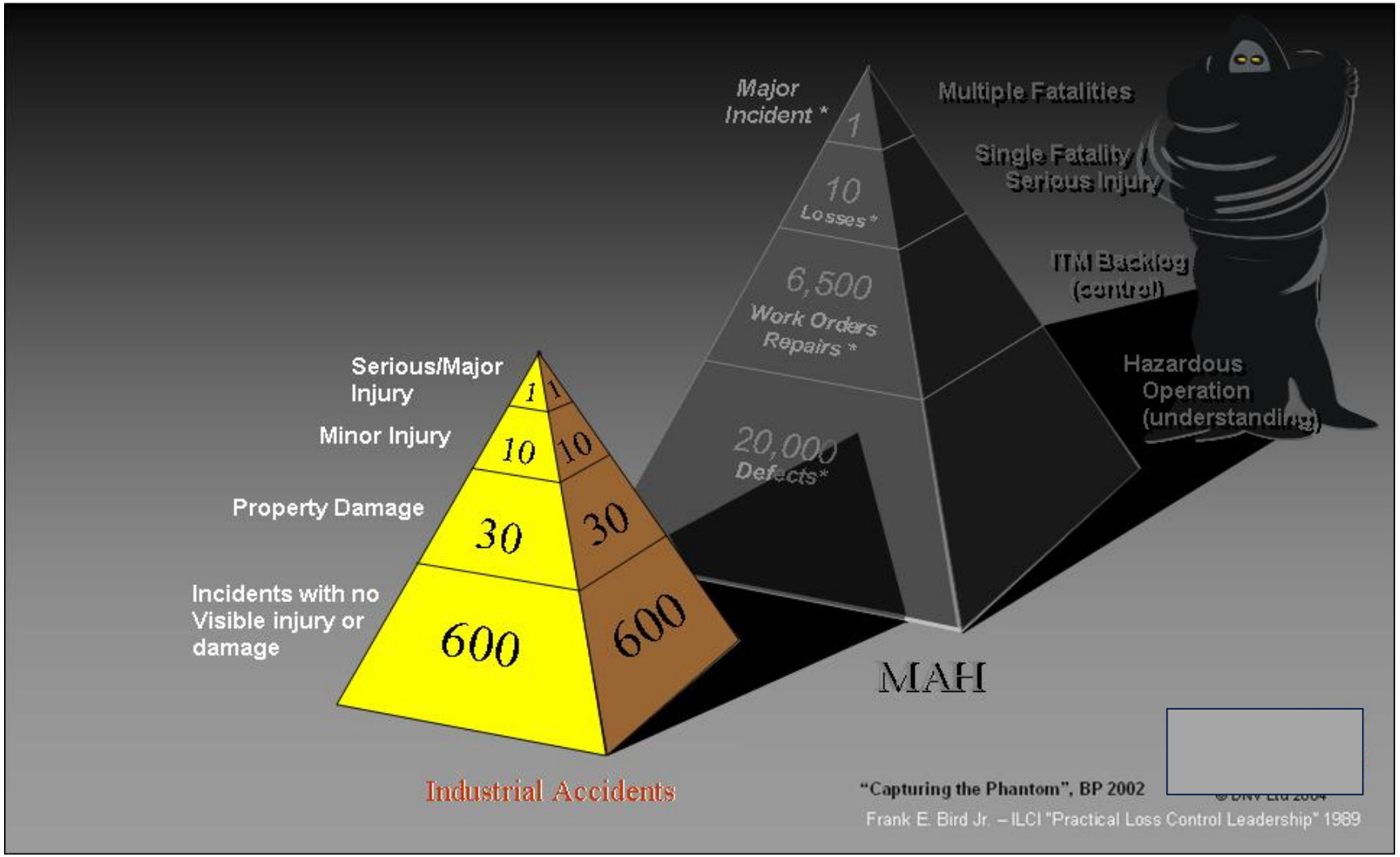
Safety Moment

Trevor Kletz:

- “If you think safety is expensive, then try having an accident”

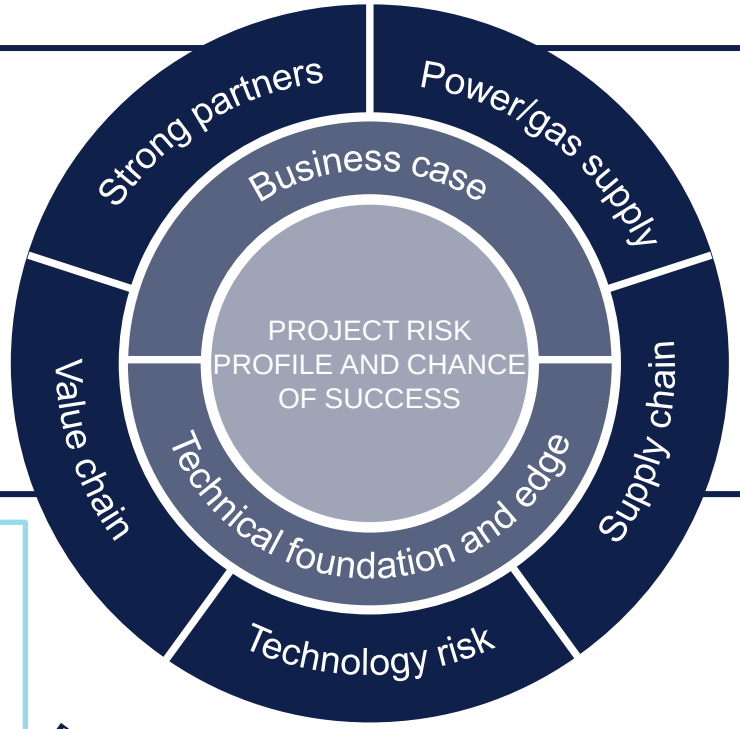


Major accident risks (black) compared to occupational safety risk (yellow)



What makes a robust hydrogen and PtX project?

- **Partnerships and market positioning**
  - Hub potential and partners
  - Access to funding and regulatory support
  - Market access and offtake strategy
  - Growth staircase with partners/clients to hedge sector exposure



- **Competitive LCOH and emission control**
  - Cost effective upstream energy supply
  - Low-cost storage and delivery solutions
  - Long term agreements or dedicated production
  - Understanding of risks through value chain
  - Control of GHG emission footprint

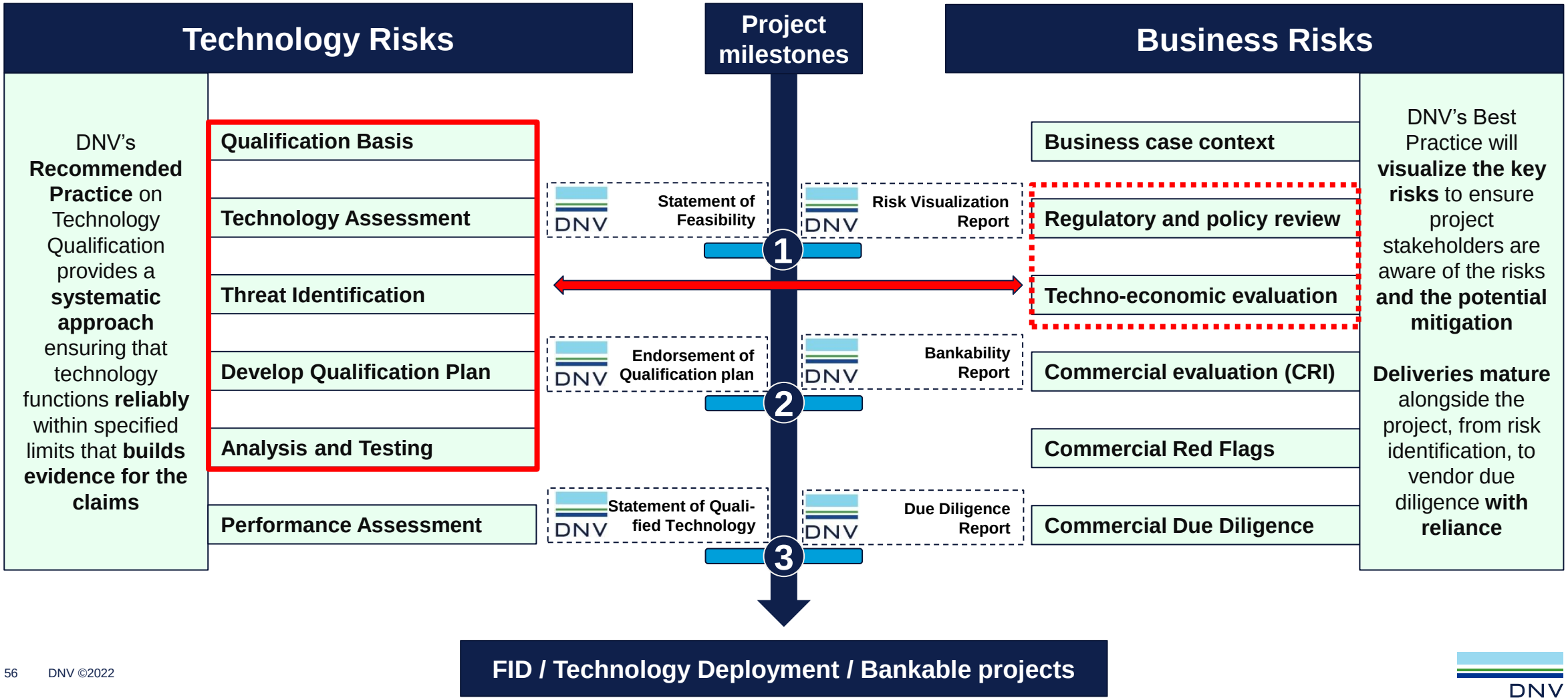
- **Supply chain control**
  - Availability of essential equipment
  - End product control – ammonia or other through suppliers and partners
  - ESG risks

Technology risk management

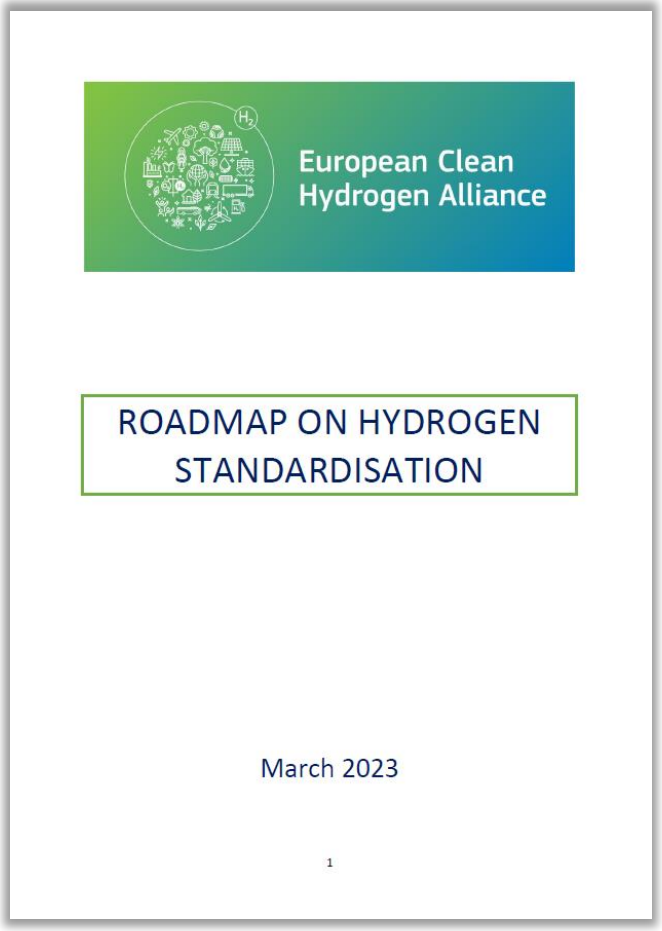
- Safety philosophy
- Control of technical and HSE risk factors
- Suitable maturity and technology risk profile
- Piloting supporting full scale development
- Control of key processes
- Favorable location for chosen technology – limited site-specific risks

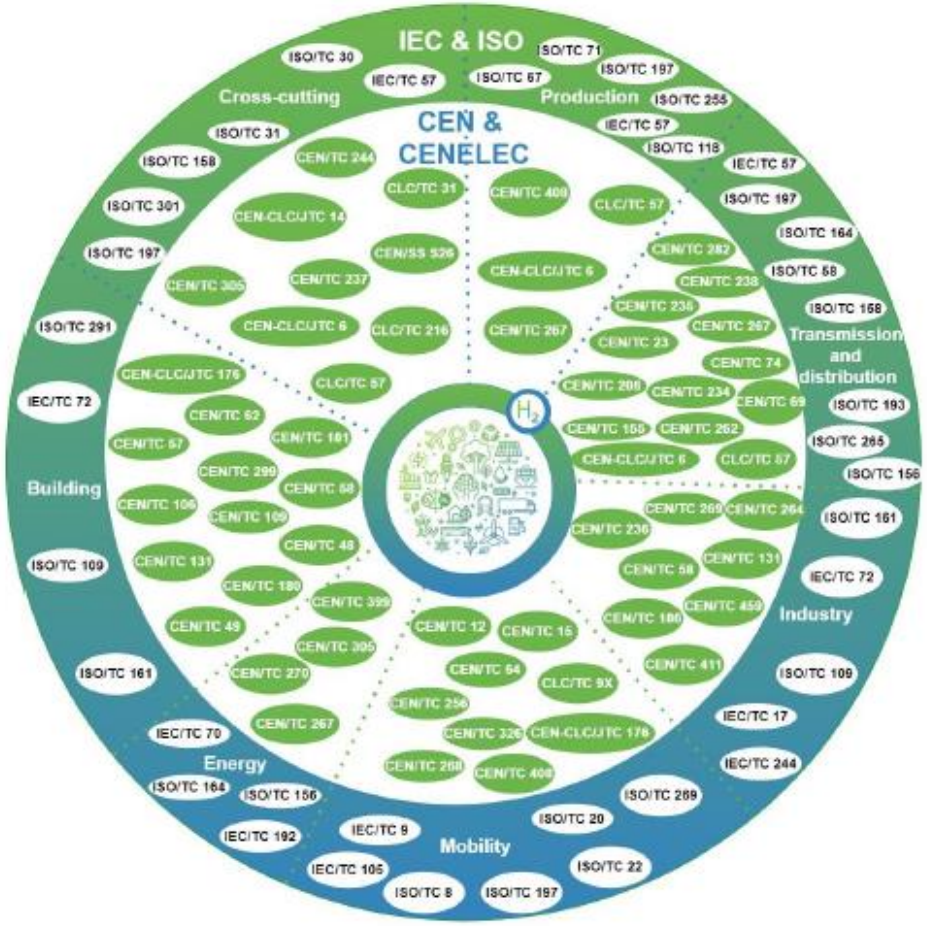
1. Make it right the first time!
2. Early involvement from knowledge partners to be due-diligent
3. Structured approach to focus on mitigating major risks and ensuring inherently safe and compliant design

Maturing technology and the business case – *by reducing risks*



European and international standardisation landscape for hydrogen topics – On the doorstep for years work





Source: European Clean Hydrogen Alliance (ECH2A) - Roadmap on Hydrogen Standardisation, March 2023

01 Introduction

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Methane & Hydrogen Explosion Comparison

Same volume (~ 7kg vs. 0.5kg)

Deflagration to Detonation Transition (DDT)

Risk & Risk Perception

- Maintaining public confidence will be important for some applications
- Risk perception will be a key factor => training, skills fo handling and awareness are key
- Need to recognise there are significant uncertainties

HOME › GENERAL › RECENT EXPLOSIONS SHUTDOWN HYDROGEN VEHICLE REFUELING IN NORCAL AND NORWAY

Recent explosions shutdown hydrogen vehicle refueling in NorCal and Norway

BY JEFF NISEWANGER *on* JUNE 11, 2019 · (1)

Explosions at a hydrogen fueling depot in Northern California and at a retail station in Norway have left owners of fuel cell cars in those regions without their usual source of refueling.

Monday's explosion in Sandvika, Norway near Oslo occurred at a hydrogen station operated by the company Uno-X adjacent to a major shopping center at around 5:30pm local time. As a result, some of the company's other fuel cell stations have been taken offline until an investigation reveals more information about the cause of the explosion.

Natural gas versus hydrogen – selected features

	Hydrogen	Natural gas
Flammable range	Ignites in a much wider mix range (4% to 75% of volume)	Narrow flammability mix range (5,3% to 15% of volume)
Ignition energy	Ignitable by low energy sources - phones, and human static electricity (0.020mJ)	10 times higher than H2 (0.29mJ)
Flame velocity	3.2 m/s 8 times faster flame velocity than NG - much higher explosion pressure potential - detonation possible which requires higher focus on QRA & fire/explosion studies	0.4 m/s Mainly no detonation
Dispersion	Disperses much faster than NG. Limited potential for ground accumulation	Large gas cloud may form. In some conditions as heavy gas on the ground (LNG)
Regulations	SEVESO not (yet) really fit Lower TIER: 5 t Minimum Mass Tetryl 0.8 g	SEVESO & other regulations specifically include natural gas

Danish Legislation applicable for Hydrogen Infrastructure & Facilities (excerpts)

Law 2062 16/11/2021
Arbejdsmiljøloven

EO 99 af 31/01/2007 Indretning, ombygning og reparation af trykbærende udstyr
EO 1977 27/10/2021 Anvendelse af trykbærende udstyr
EO 370 af 19/04/2016 Kontrol med arbejdsmiljøet ved risiko for større uheld
EO 478 af 10/06/2003 Arbejde i forbindelse med eksplosiv atmosfære
EO 1793 af 18/12/2015 Arbejde med stoffer og materialer
EO 1794 af 18/12/2015 særlige pligter for fremstillere, leverandører og impo
stoffer og materialer efter lov om arbejdsmiljø
EO 1234 af 29/10/2018 Arbejdets udførelse
ETC. (***more than 100 Executive Orders*** under Arbejdsmiljøloven)

Law 61 30/01/2018
Gassikkerhedsloven

Law 26 10/01/2019
Elsikkerhedsloven

Law 155 20/02/2013
Indretning af visse produkter

Law 30 11/01/2019
Autorisation af virksomheder på el-, vvs- og kloakinstallationsområdet

EO 253 af 04/04/2018 Sikkerhed for gasanlæg
EO 239 af 23/03/2018 Sikkerhed for gasmateriel
EO 1082 af 12/07/2016 Sikkerhed for udførelse og drift af elektriske installationer
EO 247 af 26/03/2018 Sikkerhed for gasinstallationer
EO 289 af 17/03/2016 Elektrisk materiel og elektriske sikringssystemer til anvendelse i en potenti
eksplosiv atmosfære
EO 514 af 16/10/1981 Forskrifter for udførelse af gasinstallationer
EO 1608 af 20/12/2017 Sikkerhed for drift af elektriske anlæg
EO 1114 af 18/08/2016 Sikkerhed for udførelse af elektriske anlæg
1112 af 18/08/2016 Sikkerhed for udførelse af ikke-elektrisk arbejde i nærheden af elektriske anla
ETC. (***more than 40 Executive Orders*** under Gassikkerhedsloven, Elsikkerhedsloven, Indretnin
produkter and Autorisation af virksomheder)

Law 314 03/04/2017
Beredskabsloven

EO 2341 af 09/12/2021 Brandsyn
EO 590 af 26/06/2003 Klassifikation af eksplosionsfarlige områder
EO 1444 af 15/12/2010 Tekniske forskrifter for gasser
EO 348 af 11/06/1998 Bedriftværn
ETC. (***more than 30 Executive Orders*** under Beredskabsloven

Law 100 19/01/2022
Miljøbeskyttelsesloven

Law 1376 21/06/2021
Miljøvurderingsloven

EO 372 af 25/04/2016 Kontrol med risikoen for større uheld med farlige stoffer
EO 2080 af 15/11/2021 Godkendelse af listevirksomhed
EO 2079 af 15/11/2021 Standardvilkår i godkendelse af listevirksomhed
GUIDE 14004 af 01/02/1990 Pligter ved risikobetonede aktiviteter
ETC. (***more than 120 Executive Orders*** under Miljøbeskyttelsesloven and Miljøvurderingsloven

Law 100 19/01/2022

EO 372 af 25/04/2016 Kontrol med risikoen for større uheld med farlige stoffer
EO 1534 af 09/12/2019 Godkendelse af listevirksomhed

Standards

TECHNICAL REPORT

ISO/TR 15916

Second edition
2015-12-15

Basic considerations for the safety of hydrogen systems

Considérations fondamentales pour la sécurité des systèmes à l'hydrogène

Reference number
ISO/TR 15916:2015(E)

Important: Being a capable and purpose driven organization to influence the Hydrogen Industry

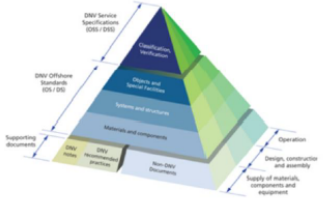
Member, International Organizations and Committees

80 different standardization committees under e.g. ISO and CEN ->

United Nations Global Compact (UNGC)	World Business Council for Sustainable Development (WBCSD)	International Association of Classification Societies (IACS)	World Energy Council (WEC)	International Gas Union (IGU)	Fire and Blast Information Group (FABIG)
American Gas Association (AGA)	International Standard Organization (ISO)	Institute of Chemical Engineers (IChemE)	The Welding Institute (TWI)	Pipeline Simulation Interest Group (PSIG)	Energy Institute
American Petroleum Institute (API)	National Association of Corrosion Engineers	European Federation of National Engineering Associations	Royal Meteorological Society (RMetS)	Institute of Risk Management (IRM)	Energy Industries Council (EIC)
Institution of Gas Engineers and Managers	Institute of Environmental Management & Assessment (IEMA)	International Institute of Risk and Safety Management (IIRSM)	American Chemical Society	Institute of Corrosion	Conformity Assessment Body Forum CABF)
International Council on Large Electric Systems (CIGRE)	European Safety and Reliability Data Association (ESReDA)	British Institute of NDT	American Society of Mechanical Engineers	Oil and Gas UK	Norwegian Oil and Gas Association (NOROG)

89 memberships of International Organizations

DNV Standardization Organization



The barriers for policies to overcome

Pathway to a green hydrogen verification regime – Hydrogen standards and certification processes in Europe

DNV is performing an assessment of green hydrogen standards and certification schemes in the EU, UK and Norway. This includes

- Mapping the standards and certification schemes in place and in development;
- Providing insights into the key trade-offs and issues inherent in the various standards, including with respect to additionality;
- Assessing the likely policy developments in the EU that may impact on these standards, including in the context of RePowerEU and the EU's desire to reduce dependence on Russian gas;
- Recommending an optimal solution for Statkraft to pursue in project development.

DNV's role

DNV's scope of work includes:

1. **Green hydrogen in the European energy transition**
   - Including EU Fit for 55 and REDII revision, UK RTFO and LCHS, Norway hydrogen and CfD mechanism
2. **RePowerEU: The potential EU hydrogen policy rethink**
3. **Standards and schemes**
   - Including CEN standard and voluntary certification schemes
4. **Optimising the solution**
   - Including gap analysis & risk/reward; defining an optimal approach for Statkraft; and strategic recommendations

Project details

Customer	Statkraft
Country	Norway, EU, UK
Date	2022

Axel.Dombrowski@dnv.com | +49 40 36 149 74 08

Certification of electrolysers

Challenge

Hydrogen is expected to have a key role in decarbonisation efforts across regions and industries.

Power-to-Gas (P2G) as a future technology will play a central role in successful sector coupling and green hydrogen could be competitive with hydrogen from fossil fuels as early as 2030.

"At the present the scaling of green hydrogen mainly produced from water by renewables-powered electrolysis poses high uncertainties and needs support from the beginning, specially support by standardisation (in tests)", so that DNV can play an important role, together with industrial partners.

Solution

Set up a global acknowledged certification scheme for electrolysers to respond quickly to the demand of associations, industry partners, electrolyser manufacturers, grid operators, banks and insurance companies based on the JIP-report. Main principles for the product and processes certifications will be Safety, Performance and Regulatory.

Benefits

- Transparency and guidelines for all stakeholders
- Binding link / No competition with existing standards
- First global certification scheme for electrolysers
- Comparability between electrolysers

Value

- Acceleration of authorization procedure by certification and test
- Define quality and service life of electrolyser systems
- Define safe production (storage) under renewable energy sources
- Efficiency/performance/comparability parameters of electrolysers

Project details

Customer	25+ participants
Country	EU
Date	2022 – Ongoing

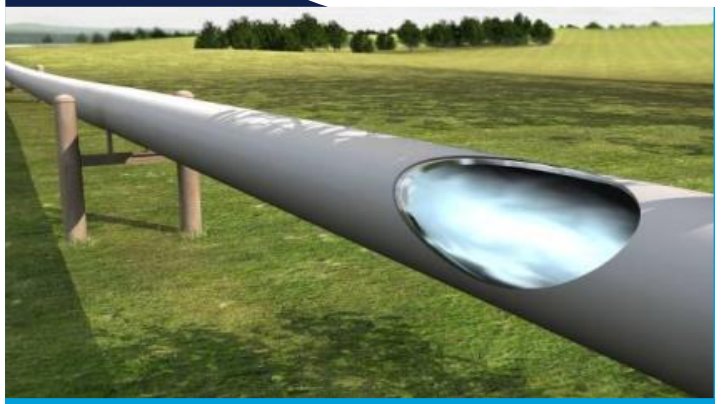
Helping scale CCS – 200+ projects in past 10 years

CAPTURE

- Coal and gas fired power plants
- Gas processing, cement, steel, WtE
- BECCS and Direct Air Capture

- Conceptual designs
- Feasibility studies (pre-FEED)
- High level cost estimations
- Technology review and benchmarking
- Due Diligences
- Qualifications and risk assessments
- Carbon removal verifications
- Market consultations

TRANSPORT



- Pipelines
- Ships

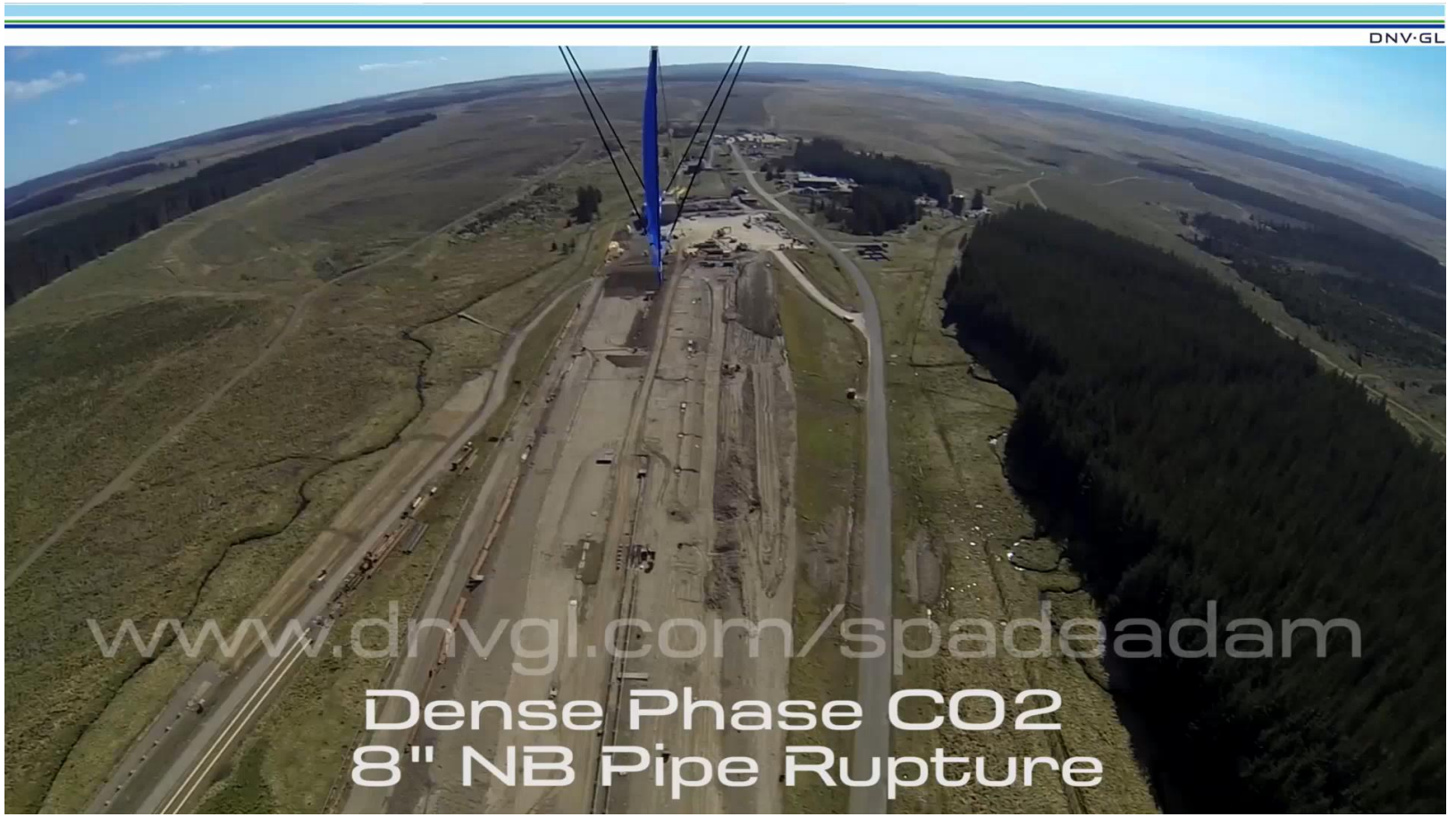
- Corrosion
- Material selection and structural design
- Flow assurance and operational issues
- Accidental release and dispersion
- Concept design and AIP for CO_2 ships
- Requalification of infrastructure
- Qualification of novel ship concepts
- Ship Classification

STORAGE

- Depleted oil or gas reservoirs
- Saline aquifers
- Enhanced oil recovery (EOR)

- Verification of storage sites
- Permanence of storage
- Risk management
- Monitoring and verification
- Public concern
- Transfer of responsibility
- Injection Facilities

CO2 pipeline rupture test at DNV Spadeadam



CO2 pipeline fracture propagation test at DNV Spadeadam

Testing and Tools

DNV Groningen
- Multi-phase flow laboratory

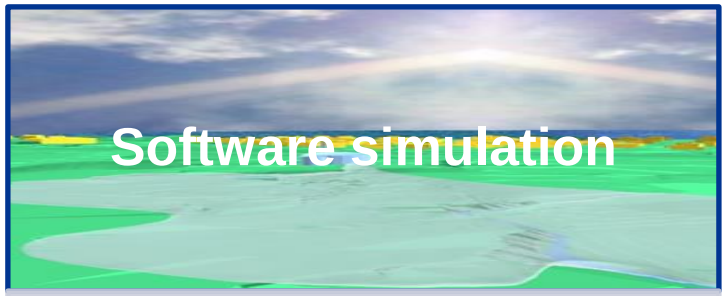
DNV Columbus
- Materials performance and testing laboratory

DNV Norway (Oslo + Bergen)
- Materials, components and structures performance and testing laboratory

DNV Spadeadam
- Major Hazard Research testing and training
- Full scale integrity, corrosion and safety tests specifically for CO_2 applications

Technology Centre Mongstad
- Strategic collaboration with Technology Centre Mongstad and Sintef to test new capture technologies

TECHNOLOGY CENTRE MONGSTAD



KFX CO_2 software
- Simulates CO_2 releases from storage facilities, pipelines, trucks or ships.
- Takes complex thermodynamics and interaction between geometry and terrain into account, including dry-ice formation and sublimation of CO_2.

Driving development of first international CCUS standards

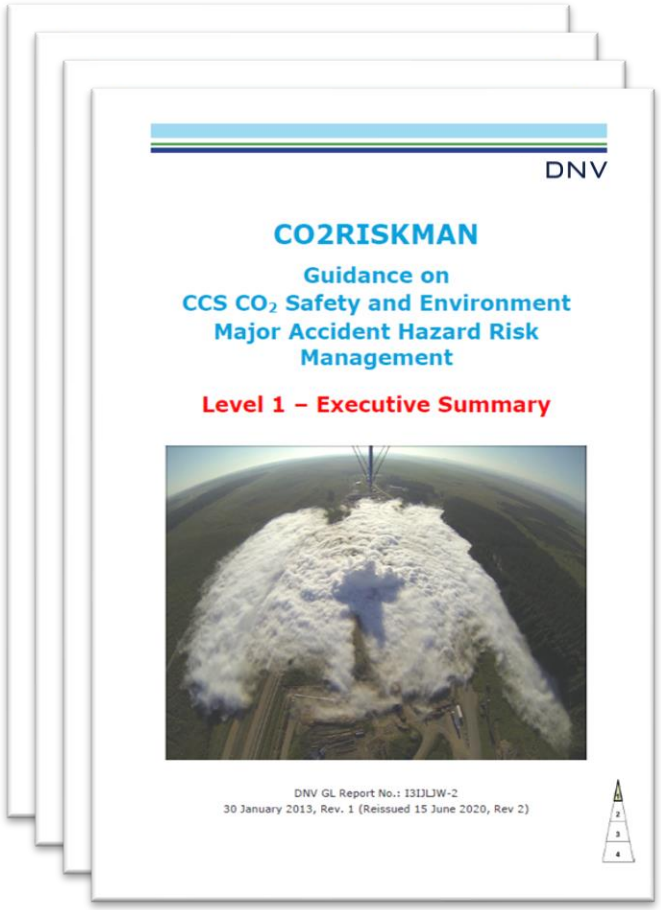
DNV RESEARCH/JOINT INDUSTRY PROJECT

↓

- CO2 RISKMAN – Guidance on CCS CO_2 Safety and Environment Major Accident Hazard Risk Management
- CO2 PIPETRANS – Guidance on transportation component of CCS projects
- CO2 SAFEARREST – Guidance on the efficient design of CO_2 pipelines
- CO2 QUALSTORE – Guidance for the selection and qualification of CO_2 storage sites
- CO2 WELLS – Guidance on the risk management of existing wells at CO_2 storage sites
- CO2 CAPTURE – Guidance on procedure for capture technology qualification
- HiPerCap – Development of novel Capture technologies
- ECO2 – Best environmental practice for offshore CO_2 injection

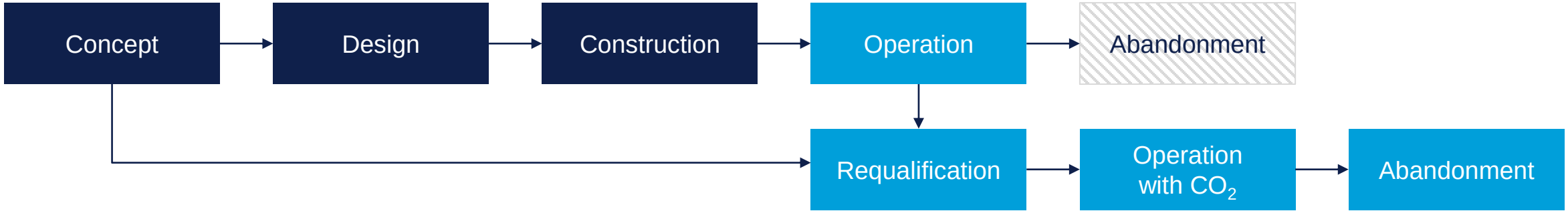
DNV RECOMMENDED PRACTICE	**DNV-RP-J201** Qualification procedures for carbon dioxide capture technology	**DNV-RP-F104** Design and operation of carbon dioxide pipelines	**DNV-RP-J203** Geological storage of carbon dioxide
INTERNATIONAL STANDARD	**ISO 27919-1** Carbon dioxide capture – Performance evaluation methods for post-combustion CO_2 capture integrated with a power plant	**ISO 27913** Carbon dioxide capture, transportation and geological storage – Pipeline transportation system	**ISO 27914** Carbon dioxide capture, transportation and geological storage – Geological storage
DNV FRAMEWORKS FOR ASSURANCE SERVICES	**DNV-SE-0160** Technology qualification management and verification	**DNV-ST-F101** Submarine pipeline systems	**DNV-SE-0473:** Certification of sites and projects for geological storage of CO_2 **DNV-SE-0617:** Qualification management for geological storage of CO_2

Guidance on CCS CO_2 major accident hazard risk management



Re-qualification of pipelines for CO_2 service

UK, Norway, Germany, Canada and Australia



SOLUTION

DNV's structured includes:

- Hydraulic analysis (pipeline capacity/phase behaviour)
- CO_2 quality (source)
- Safety (dispersion)
- Fracture control (Linepipe/weld properties)
- Integrity assessment (current and future condition)

Advice to the client based on combined findings.

RECOMMENDED PRACTICE

DNVGL-RP-F104

Design and operation
of carbon dioxide pipelines

Certification of sites for geological storage of CO_2

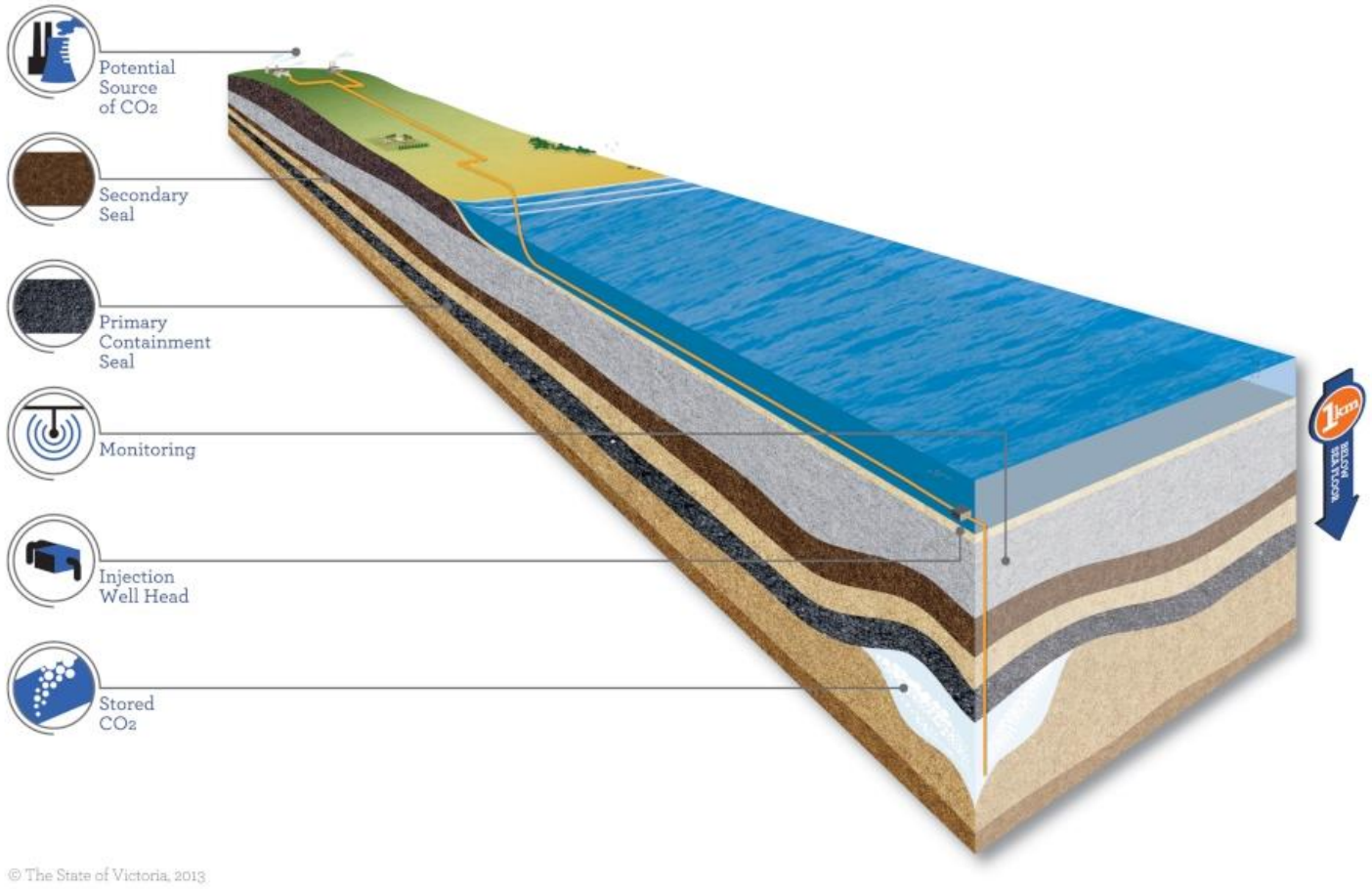
Press release

Project Greensand | CO2 storage | North Sea | Denmark

25 November, 2020

Project Greensand: North Sea reservoir and infrastructure certified for CO2 storage

The mission to store CO2 beneath the Danish North Sea has cleared the first major hurdle after the intended subsea reservoir was confirmed feasible for CO2 injection by independent certification body DNV GL to the endorsement of Danish authorities. With this certification of feasibility to DNV GL's Carbon Capture and Storage certification regime and the international standard, Project Greensand has successfully completed the first phase of validation of the project aiming to develop capacity to deliver a significant part of Denmark's CO2 reduction target by reusing discontinued offshore oil fields.



01 Introduction

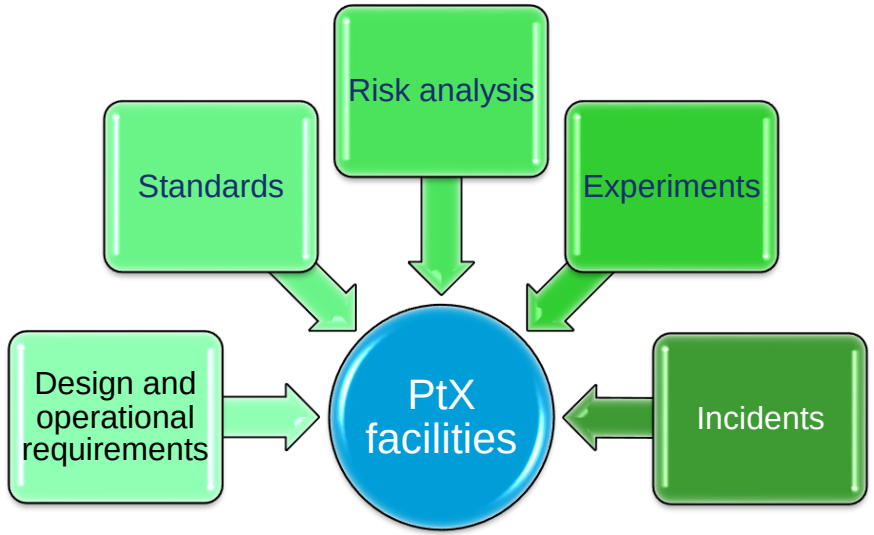
02 CO2 & Hydrogen safety properties

03 Manage safe up-scaling

04 Standardisation

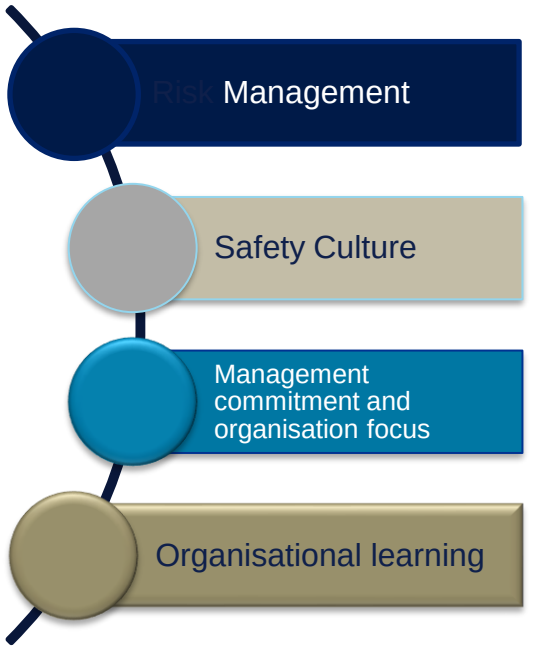
Introduction the scaling challenges

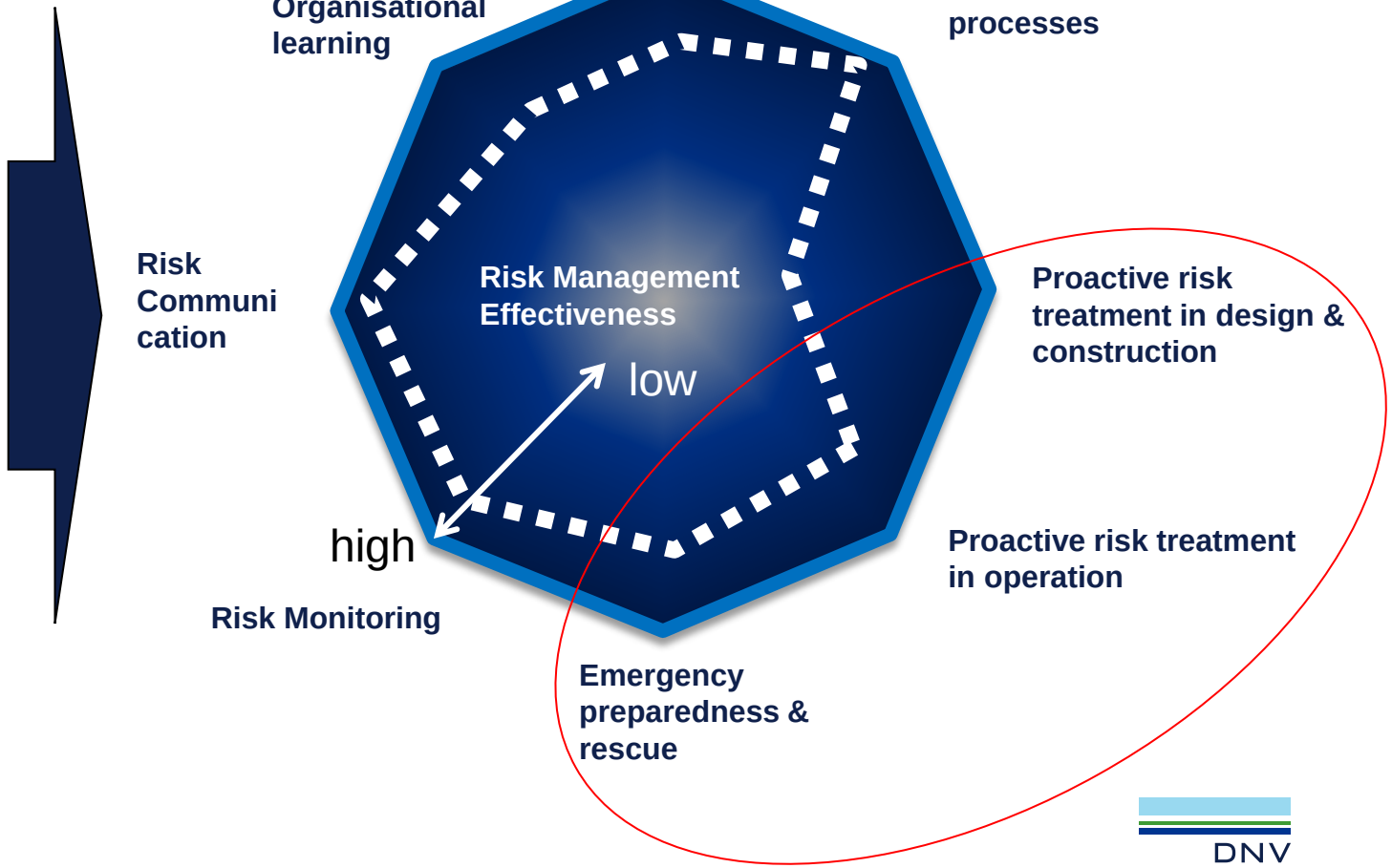
- Hydrogen & Ammonia are most mature green technology for the larger transport segments
  - ➢ Hydrogen technology is mainly developed for smaller scale facilities
  - ➢ Ammonia technology is available at large scale but applied mostly on dedicated industrial sites
- Several projects are planned with a siting plan next to grid connection and closer to cities, etc.
- Partially new operators without large scale background in hazardous material handling
- **Standards and regulations are less developed** for larger scale facilities
- Hydrogen experiments are available mostly at smaller scales
- Explosions are known to be super-sensitive to upscaling
- Simulation tools for risk assessments are available for large scale plants, hydrogen requires more qualification



We have learned that major accident risk can be controlled through some key elements

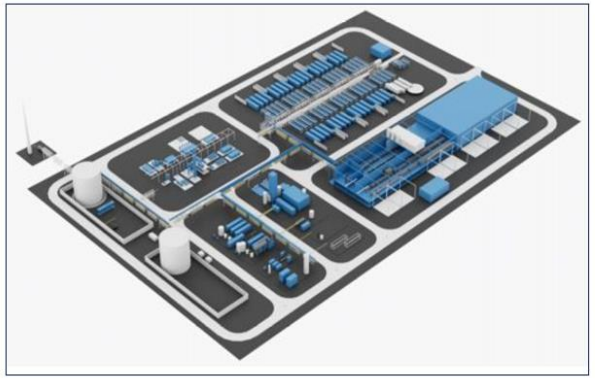
Safety improvements have been driven by accidents

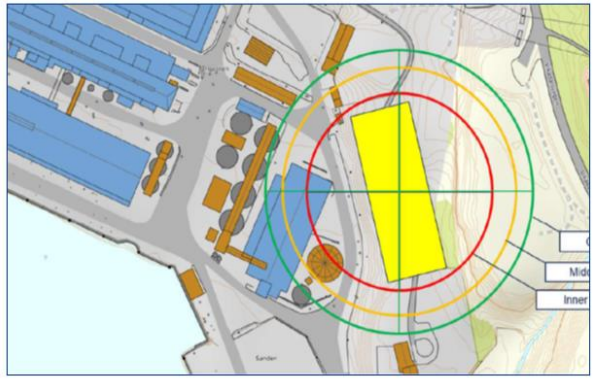




Advanced modelling and qualification of software load factors to be taken into account (DNV JIP)
-> Both local and global risk

Siting study is critical to ensure inherent safety
Also consider total risk from all facilities





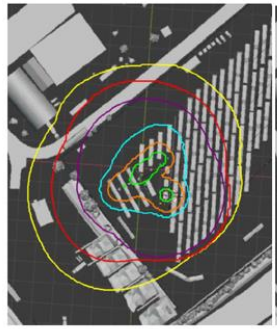
- Consider total aggregated risk from all facilities
- Domino effects barrier management
- Integrity damages due to pressure waves from explosions/detonations?

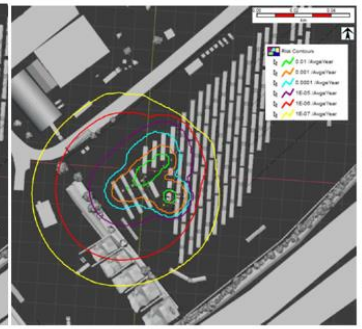
- Distinguish between
  - «inside» and «ouside» the fence
  - Size of the plant: Upscaling into GW does change the risk picture!

- Combined plants of hydrogen & ammonia require additional efforts
- Industry clusters and e.g. port environments, urban locations, etc. need to be assessed for domino effects
- Some specifics for hydrogen need further qualification

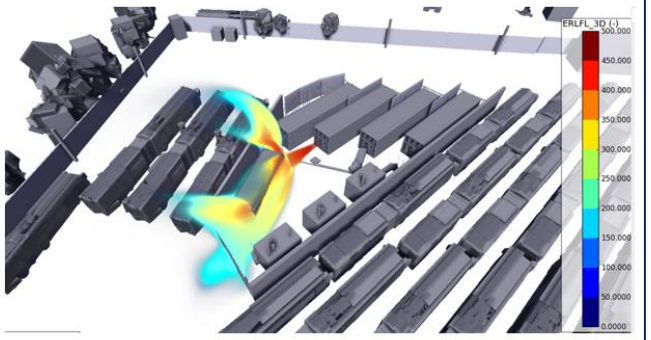
Critical leak and dispersion effects in open areas

- Without blastwalls
- With blastwall all around





Orders of magnitude numbers



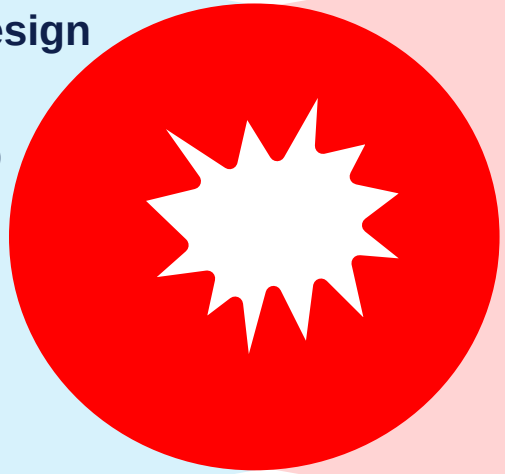
- Leak rates from 0.1 kg/s can cause critical cloud sizes (1 kg/s for methane)
- Leak duration from 1-3 s can create critical cloud sizes (10-20 s for methane)
- Gas clouds can collect at lower elevations due to jet release

Upscaled PtX ➡ upscaled measures

Using QRA actively in development show the following:

PREVENT

- <u>Inherent safe designs</u> – **avoid detonations by design**
  - Avoid gas cloud build-up in congested regions
  - Separation between equipment to prevent gas build-up
  - Improve natural ventilation by one ventilation direction
  - Reduce exposure to ammonia leakages to inherit toxicity of ammonia
- High integrity on equipment to prevent leaks
  - High quality material, welded connections, less flanges
  - High reliability on safety systems to prevent failure cases



MITIGATE

- Use blast walls if needed
- Build strong enough to prevent flying projectiles
- Drag and explosion loads found from Explosion Risk Analysis
- Fire protection need to work after an explosion
- Siting study can minimize most relevant risk
- Technology assessments help to balance safety and economy

CFD, QRAs and experiments ➡ robust and safe designs faster

What has to be done?

Formal and informal acceptance criteria, inside and outside the fence

Explosion and fire protection

Primary
Avoidance of explosive mixtures

Secondary
Avoidance of ignition sources

Tertiary
Inherently safe design with barriers

Gas dispersion

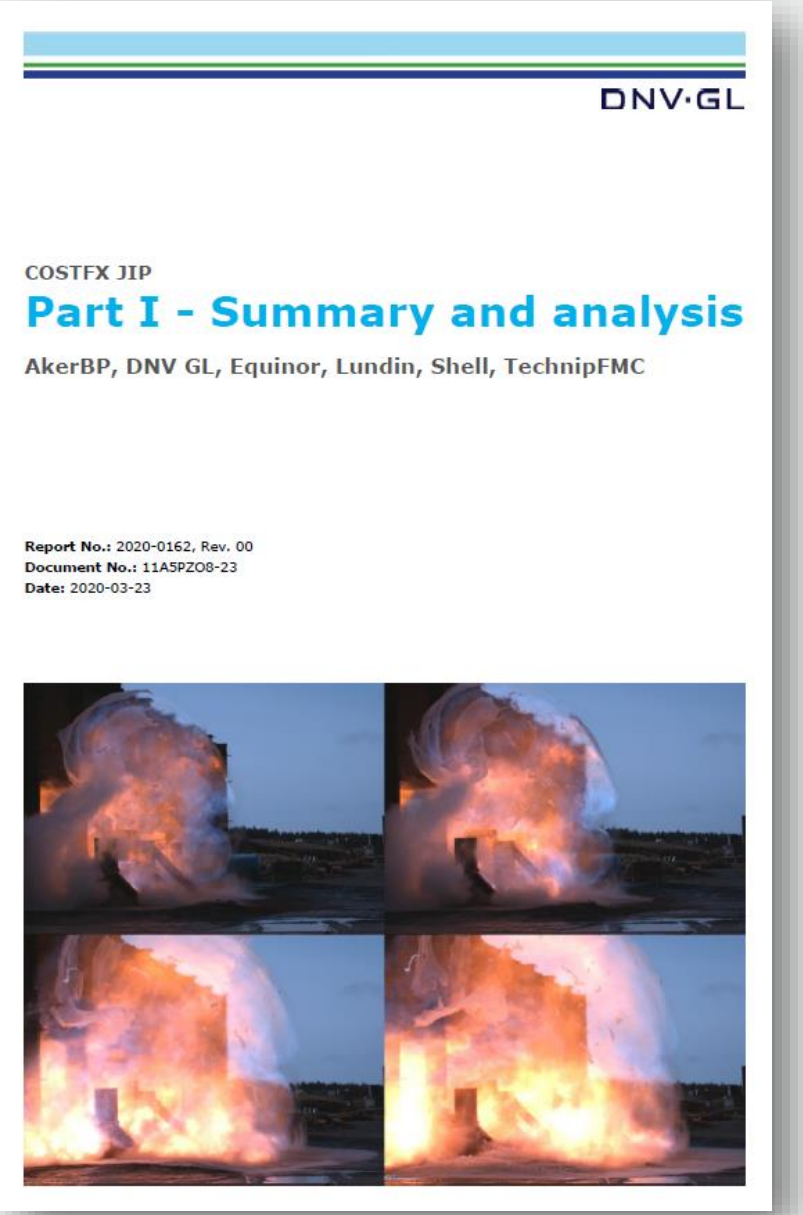
Primary
Avoid loss of containment

Secondary
Minimize amounts

Tertiary
Inherently safe design with barriers

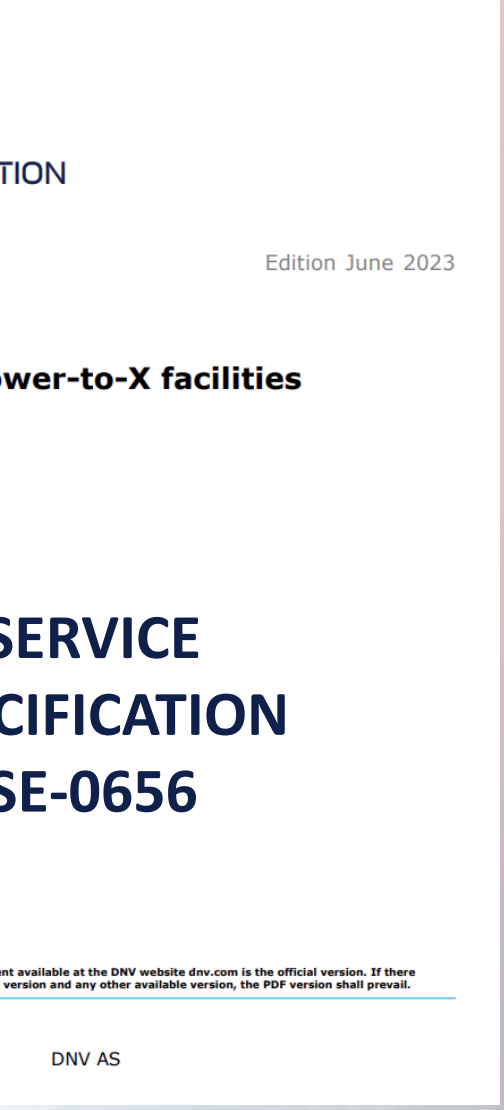
JIPs on hydrogen safety and green hydrogen, visit: DNV JIP landing page

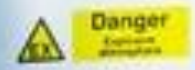
- **Example: CostFX JIP** – DNV Led. Simplify and reduced drag loading on pipe support. Experiments, CFD and Finite Element simulations.
  - Phase I with natural gas. Finished in 2020.
  - Phase II starting now. Hydrogen and Natural gas. Inhomogeneous clouds. Validation of CFD and FE codes, understanding of explosion loads. Can give improved designs and reduced cost and weight
- **H2Pipe JIP** DNV are leading a project for standardization of new and repurpose offshore hydrogen pipelines
- **Certification of Electrolyser Equipment JIP -** with partners setting the future standards for electrolysers
- **H2MET – JIP** Leading the development of hydrogen metrology
- **CO2 Safe and Sour - JIP** iincrease levels of H2S will vs. SSC



VERIFICATION OF POWER-TO-X FACILITIES

- A structured framework and methodology for the planning, preparation and execution of independent risk-based verification or certification for PtX facilities.
- Intended to minimize risks for all stakeholders, by defining assurance activities for the safe design, development, construction and operation of PtX facilities
- Focus also on interfaces and early design, affecting purchasing and equipment demands (OEM)





DNV is derisking vRES PtX and CCUS projects

Joint Industry Projects (JIP)

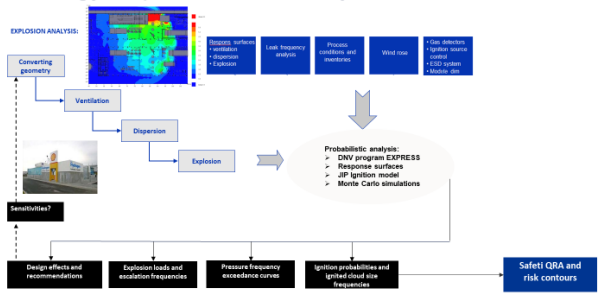
JIPs on hydrogen safety

- **CostFX JIP** – DNV Led. Simplify and reduced drag loading on pipe support. Experiments, CFD and Finite Element simulations.
  - Phase I with natural gas. Finished in 2020.
  - Phase II starting now. Hydrogen and Natural gas. Inhomogeneous clouds. Validation of CFD and FE codes, understanding of explosion loads. Can give improved designs and reduced cost and weight
- **NORTH2** – EQN Lead. Green offshore H2 in the Nederlands – DNV partner with feasibility study
- **HYDEMO** – LH2 for maritime in Norway
- **Norway-Korea H2 industry collaboration** – Innovation Norway

Regulation gaps and permitting

Modelling with Hazop and QRAs

Methodology Explosion Risk Analysis with CFD



Labs and test sites for hydrogen and CO2

Putting our expertise to the test

DNV's European laboratories and test sites for the gas industry

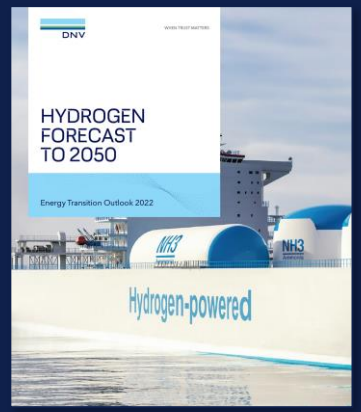
Questions?

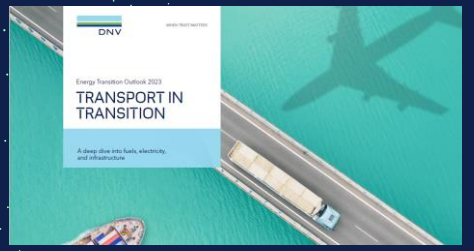
Happy to discuss!

Reach out for further details and discussions

Peter Paschke
Senior Principal Engineer
Energy Systems Northern Europe
E-mail: peter.paschke@dnv.com

www.dnv.com





Pause til kl. 14.40

Kaffe, netværk og udstillingsboder

Biogas Danmark

GREEN GAS DENMARK

2023

PtX – Aftagermarked og sektorkobling

14.40 **PtX og skibsmotorer**
Thomas S. Hansen
Head of Promotion and Customer Support, Man Energy Solutions

15.10 **Forbrug af store mængder grøn brint i Danmark**
Kristen Kristensen
Front End Development Lead – Energy Transition, Crossbridge Energy

15.40 **Forbrug af store mængder grøn brint i Danmark**
Rasmus Bernsdorf
Head of Biogas, Eurowind

Biogas Danmark GREEN GAS DENMARK 2023

MAN Energy Solutions
Future in the making

PtX- og Bio-brændstoffer i MAN ES skibsmotorer

Thomas S. Hansen
MAN Energy Solutions

Agenda

1 Future fuel mix and IMO targets

2 Ammonia engine development update

3 Methanol & Methane engines

4 Retrofit

5 Summary

Heat pumps

Decarbonization of heat supply in industry and households

Carbon Capture

Solutions for unavoidable process emissions and carbon cycles

PEM-Elektrolysis

Where electrification stops, H_2 will play a crucial role

Green propulsion

CO_2-neutral propulsion systems for shipping and power generation

Retrofits

Decarbonization of our customers' existing fleets

Decarbonization & digitalization are the drivers of our strategic development into an energy solutions provider

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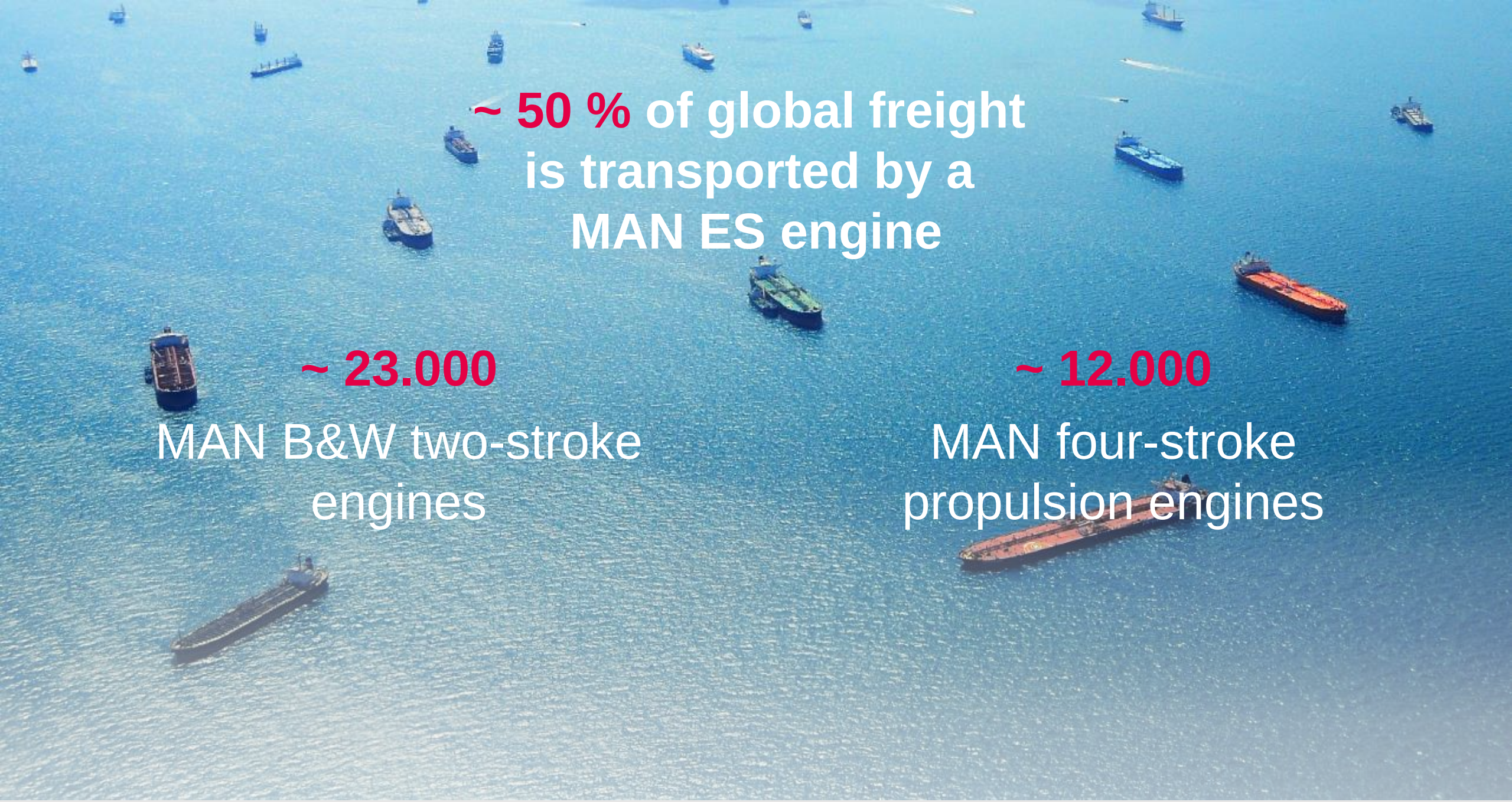


~ 50 % of global freight is transported by a MAN ES engine

~ 23.000

MAN B&W two-stroke engines

~ 12.000

MAN four-stroke propulsion engines

Powering sustainable shipping by opening clear routes

Methanol
ME-LGIM
154

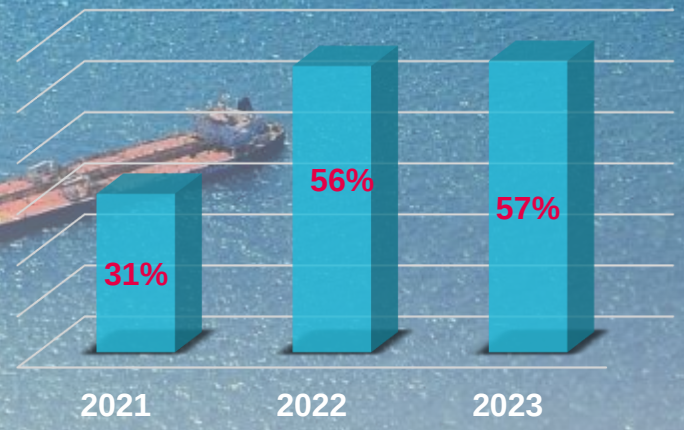
LPG
ME-LGIP
164

Ethane
ME-GIE
51

Ammonia →

Methane
ME-GI & ME-GA
621 - 268

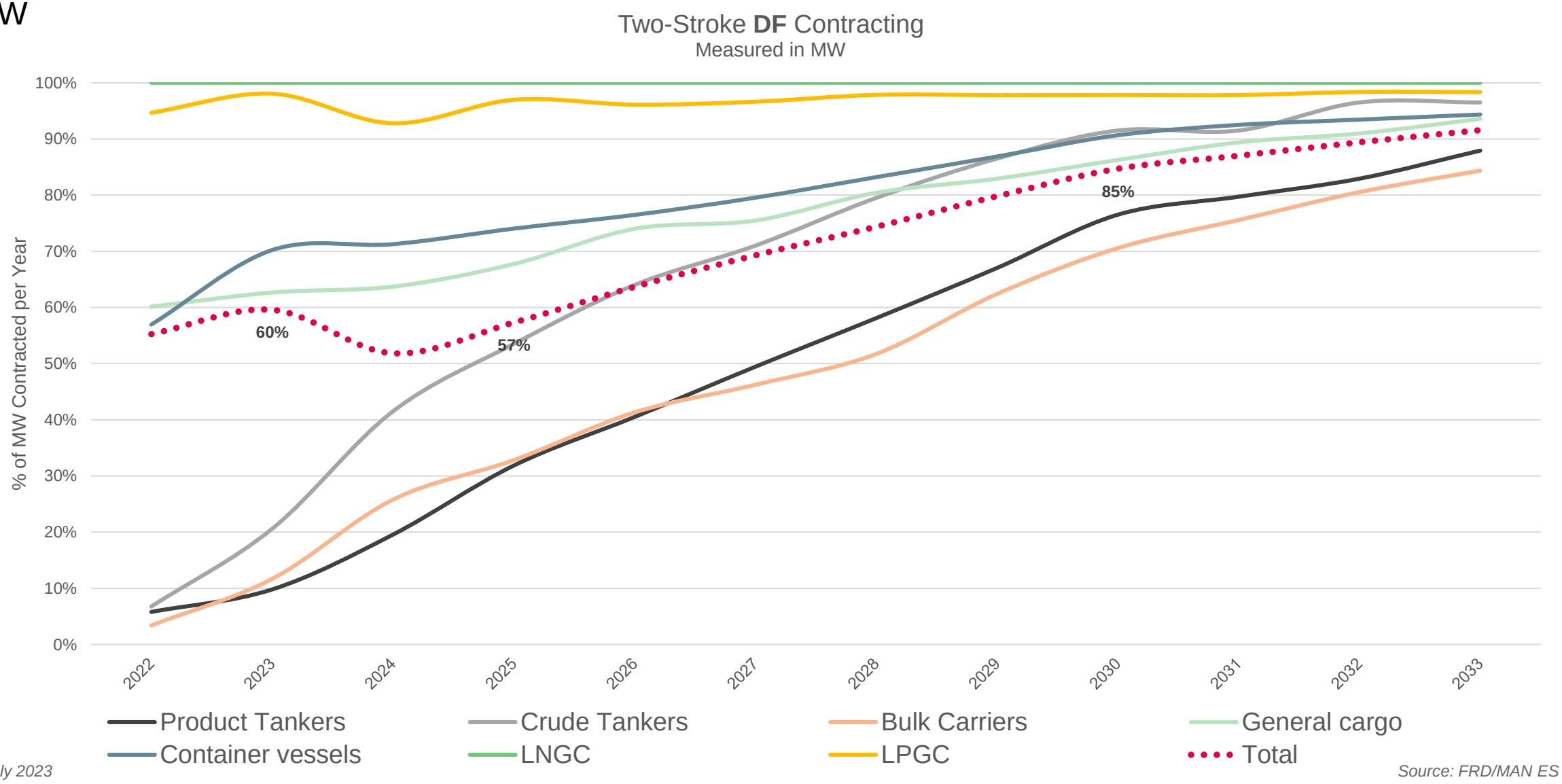
1250+
dual-fuel engine orders



Two-stroke dual-fuel share of total newbuilding market

Two-stroke dual-fuel forecast

MW

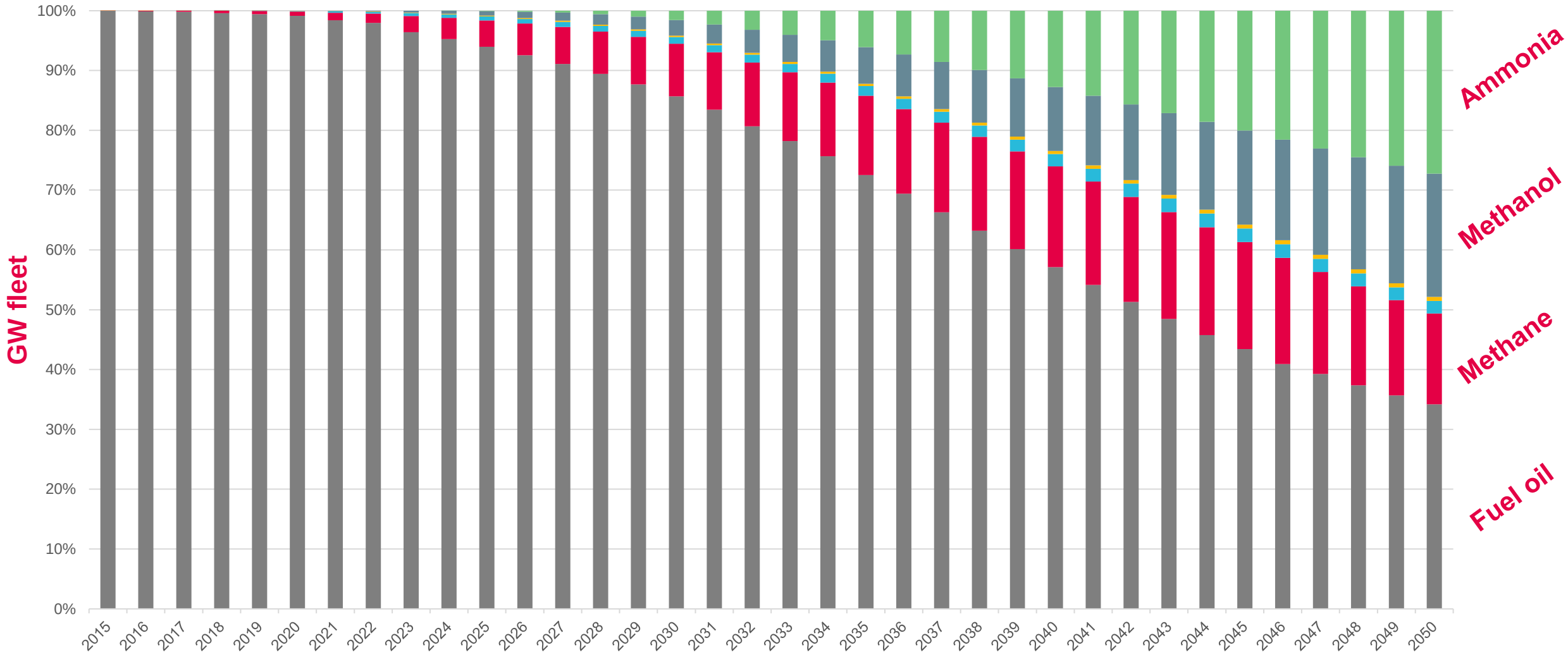


July 2023

Source: FRD/MAN ES

Two-stroke fuel mix forecast towards 2050

Forecast made before the revise IMO GHG targets of being carbon neutral in- or around 2050.

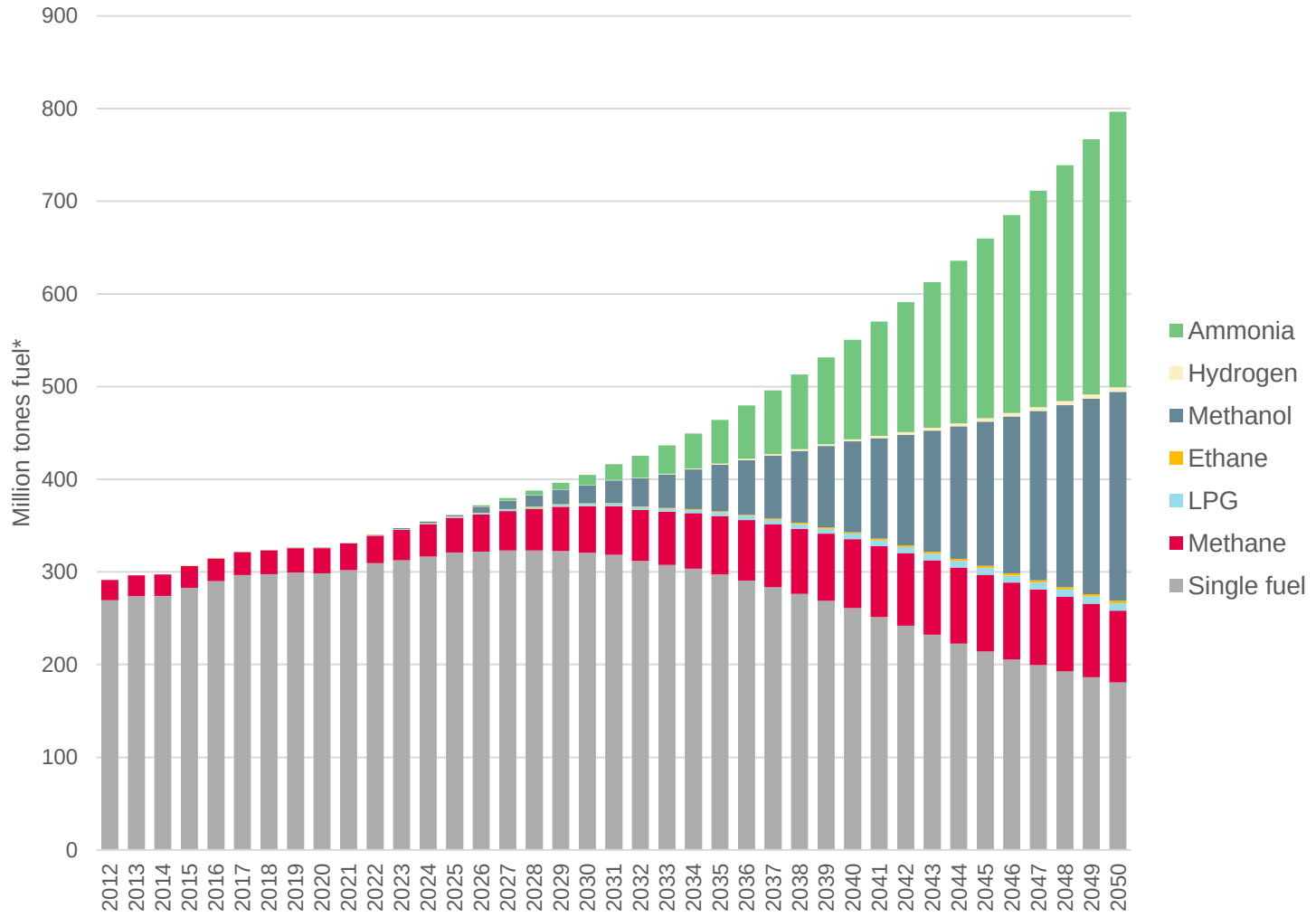


Assumptions: Scenario is based on known factors such as world trade growth, EEDI, EEXI, expected CO2 regulation (currently unspecified), etc.

Demand for ammonia, methanol and methane from shipping will be high

Expected demand from shipping alone (million tons)

Year	2030	2040	2050
Ammonia	22	141	345
Methanol	40	128	255
Methane	55	80	83



IMO GHG legislation after MEPC80

Compared to 2008, IMO targets on a *well-to-wake* perspective:

- Net zero emission by or around, i.e. close to 2050
- By 2030, 20% reduction, striving for 30%
- By 2040, 70% reduction, striving for 80%

IMO	2025	2030	2035	2040	2045	≈2050
To 2008	-0%	**-20%**	-45%	**-70%**	-85%	**-100%**

Attained through midterm measures as a

– **Fuel standard (like 0.5%S)** or

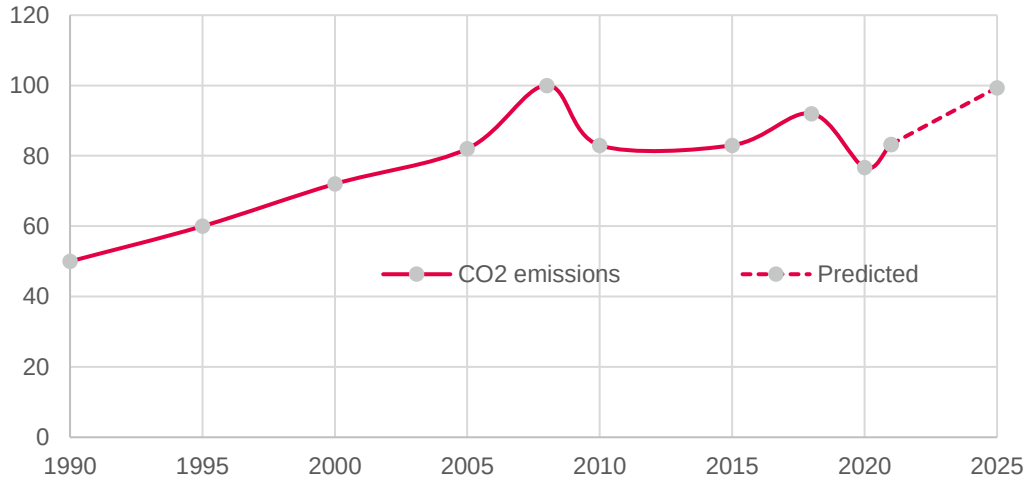
– **Fuel levy** (tax)

IMO midterm measures to be developed 2024

❑ Approval and adoption 2025

❑ Entry into force 2027

CO2 emissions from int. shipping relative to 2008



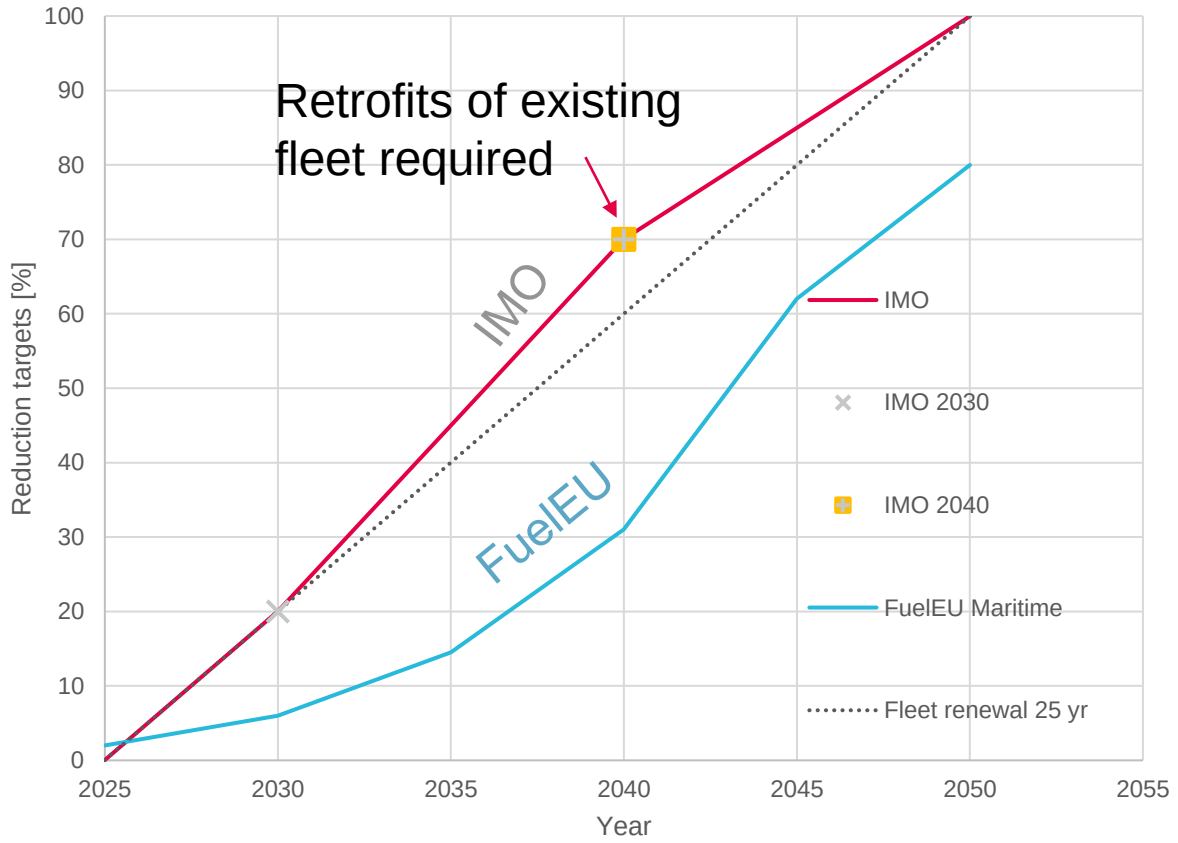
2025 industry level emissions can roughly be estimated to be similar to 2008.

CO2 emissions 1990-2018 from 4th IMO GHG study. 2020&2021 from IMO. 2025 by predicted world trade growth estimates relative to 2018.

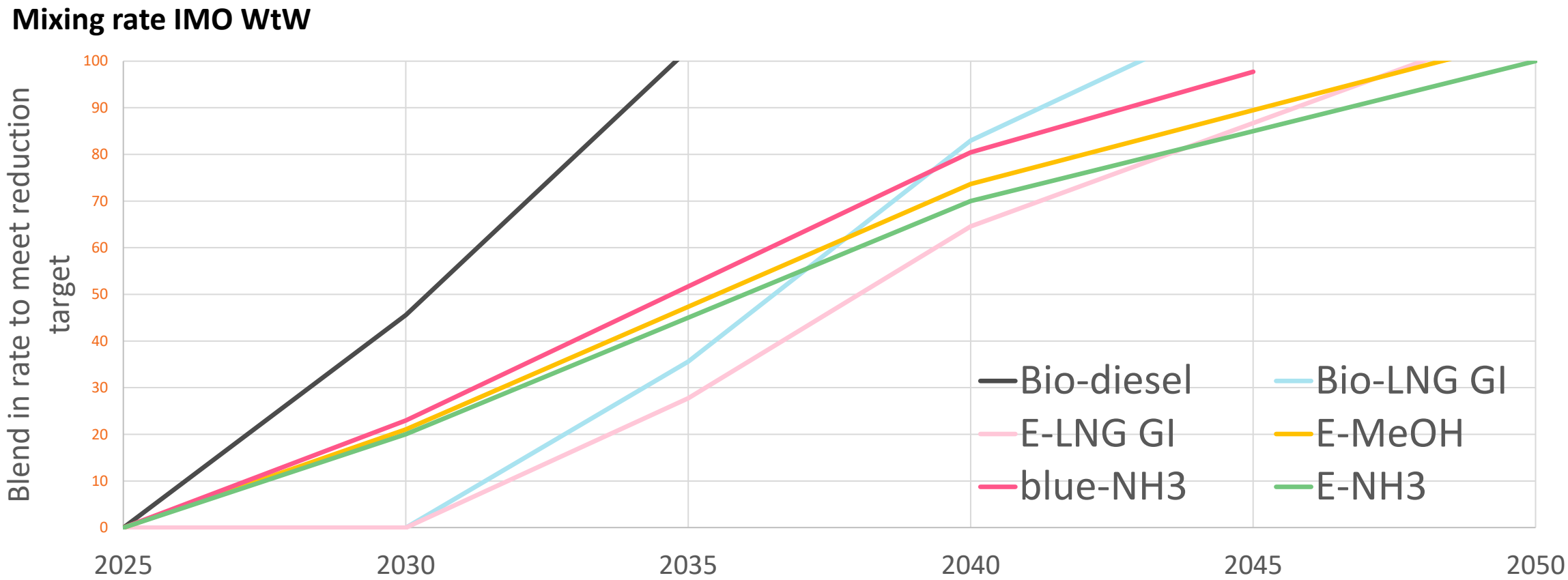
Impact from IMO GHG legislation

IMO Targets are for absolute reductions in the sector

- Maritime trade growth is expected to level out efficiency improvement.
- With an estimated lifetime of 25 years, one can assume a complete fleet renewal until 2050.
- Even if 100% of new ships going into service from now on are carbon neutral, meeting IMO 2040 target reduction of 70% will require significant retrofit of the existing fleet, if we estimate a linear propulsion power of Newbuilds.
- Advanced bio-fuels can also be used as drop in to decarbonize existing fleet.



Extensive amount of bio and E-fuels needed to meet emission targets

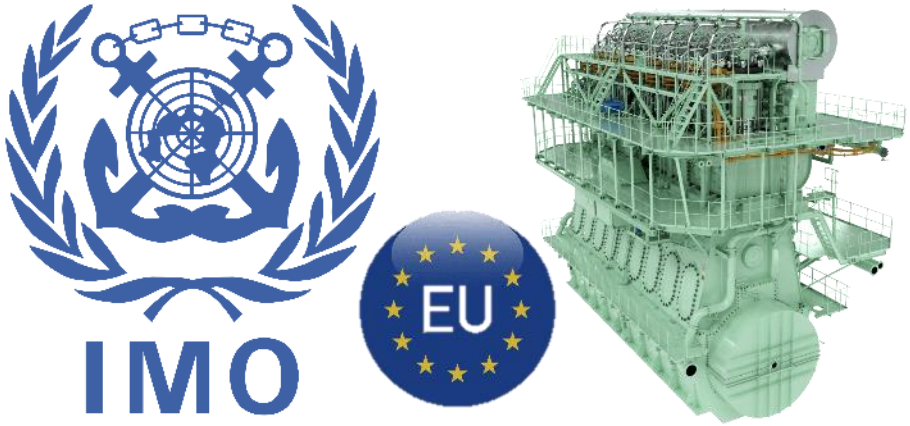


LNG, Bio-fuels and blue-ammonia can be used in the transition towards carbon neutrality.

Significant drivers in the maritime energy transition

Incentives that empower sustainable shipping

1. Legislation and ambitious emission reduction targets from shipping companies.
2. Consumer and charterer pull for carbon-neutral supply chains.
3. Technologies that enable carbon neutral propulsion are available today.
4. Green financing.
5. Large-scale orders for methanol engines providing clarity and fast-followers.



SUSTAINABLE FINANCE

Poseidon Principles

Financial institutions are committed to improving the role of maritime finance in addressing global environmental issues.

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Status at Research Centre Copenhagen

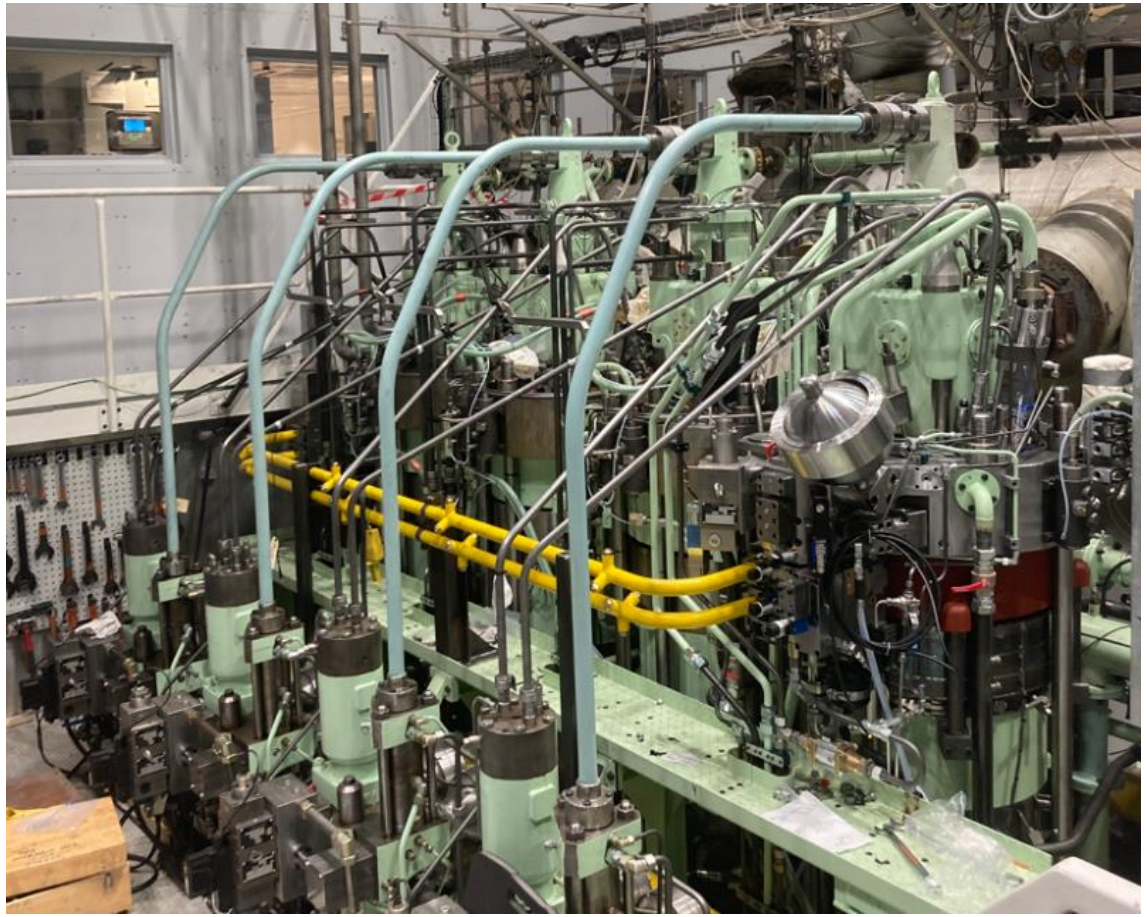
Status on the ammonia test engine

– Ammonia combustion tests started in July 2023.

– The ammonia prepared cylinder no. 4 is operated on ammonia.

– The ECS software is also being tested and verified.

– Data on the operation of the auxiliary systems are gathered and analyzed.



Ammonia engine development

The LGI combustion principle

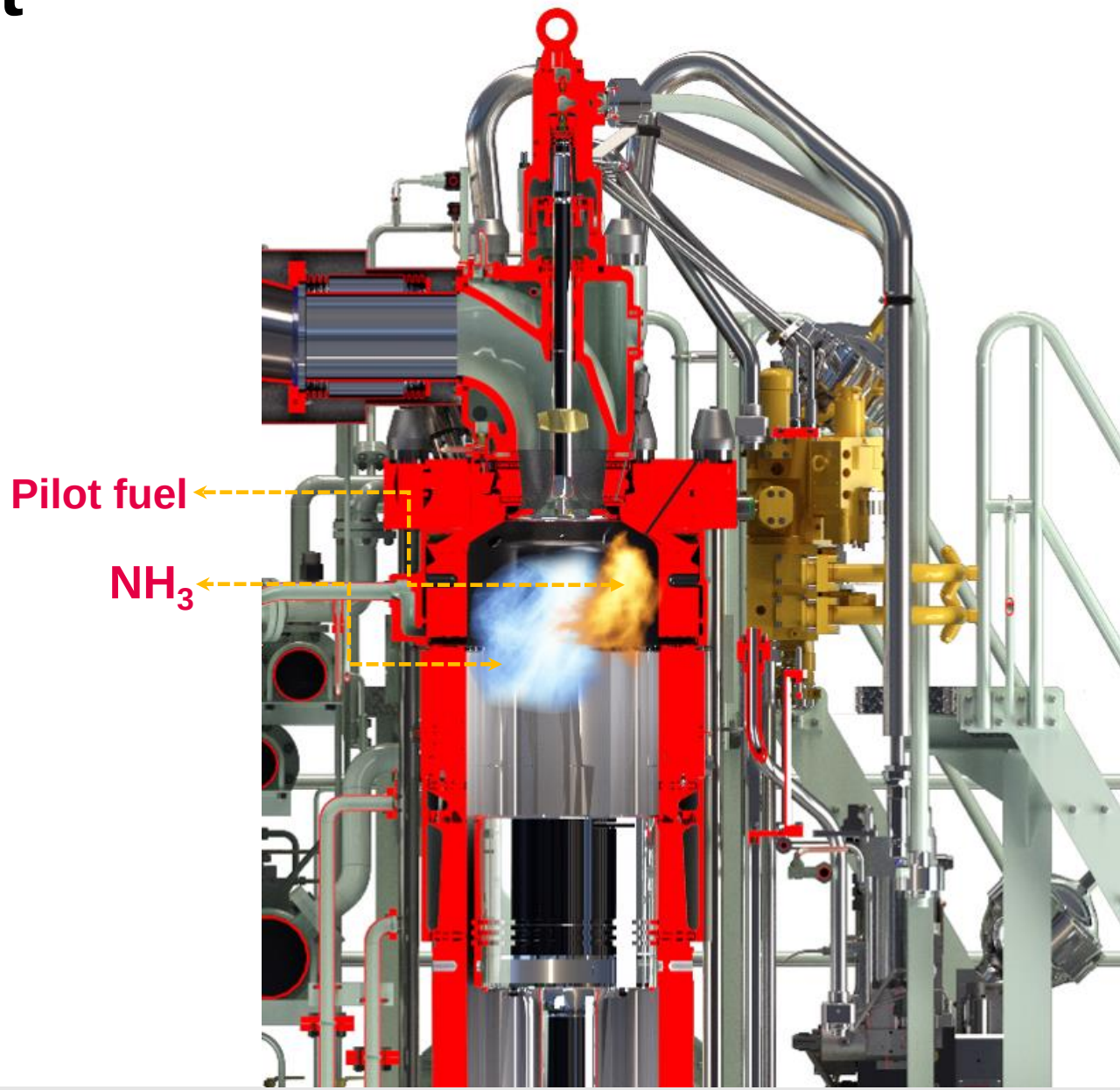
The MAN B&W ammonia engine design philosophy

“Ammonia mode”:

- Small pilot flame needed to start ammonia combustion.
- Initial tests conducted with 10-15% pilot as a first step → R&D target is around 5% pilot oil at 100% load for L1-rated engines.
- We target for same heat rate as “fuel oil mode”

“Fuel oil mode”:

- We target identical performance as a conventionally fueled engine.



Two-stroke ammonia engine main development timeline

R&D development
Copenhagen

First engine delivery
2024

Positive seagoing experience

Full sales release

Ammonia engine development

How do we handle potential Nitrous Oxide (N_2O) emissions?

N_2O is a very potent GHG with GWP of 298.

It will also be accounted for in FUELEU regulation.

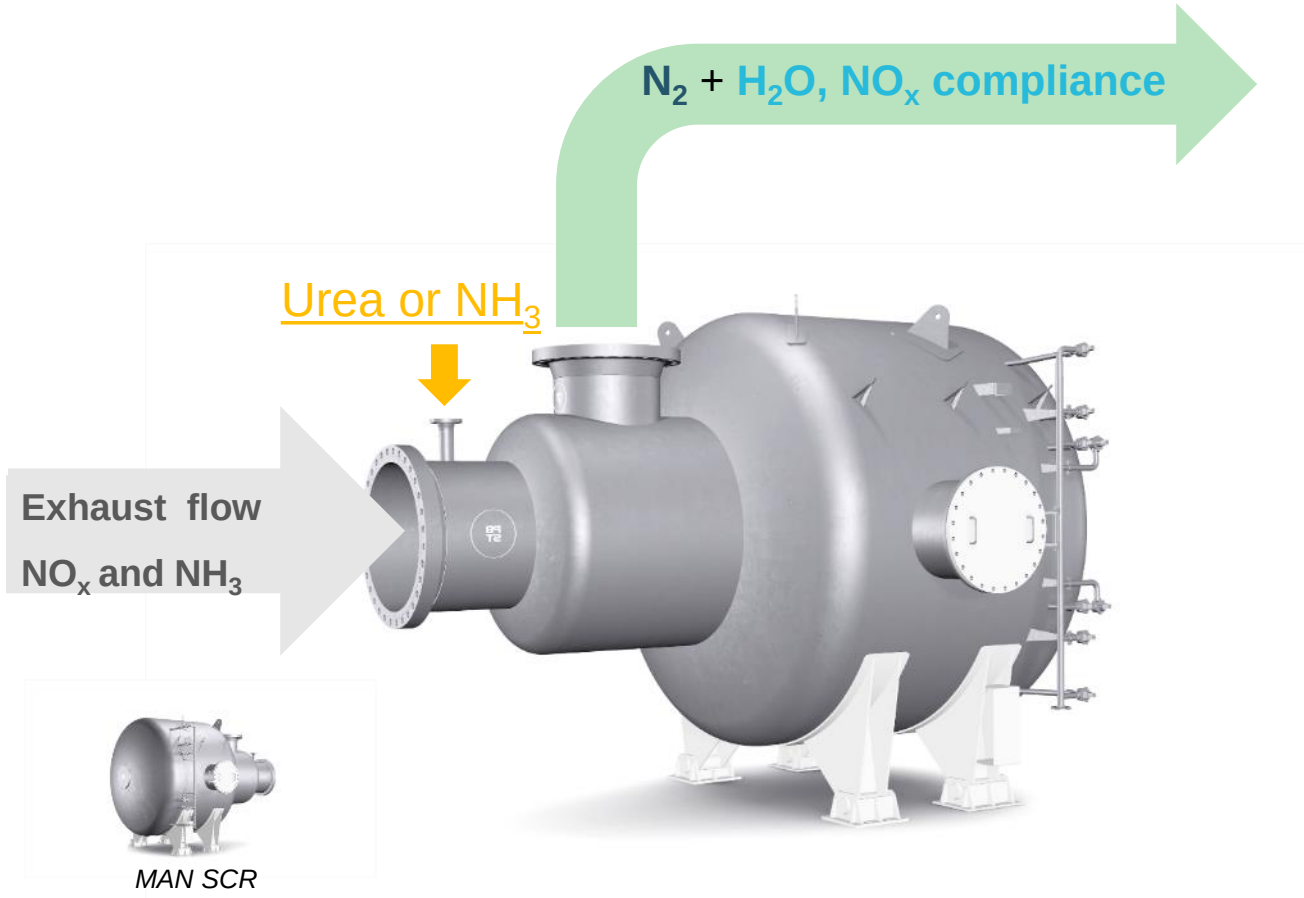
– Nitrous oxide (N_2O) will be removed by engine tuning.

Ammonia slip and NOx emissions

– Unburned NH_3 and NO_x is removed in the SCR reactor.

– Dosing of additional ammonia to SCR reaction if needed.

– Known SCR technology is suitable. MAN HP-SCR reactor can be applied.



MAN SCR

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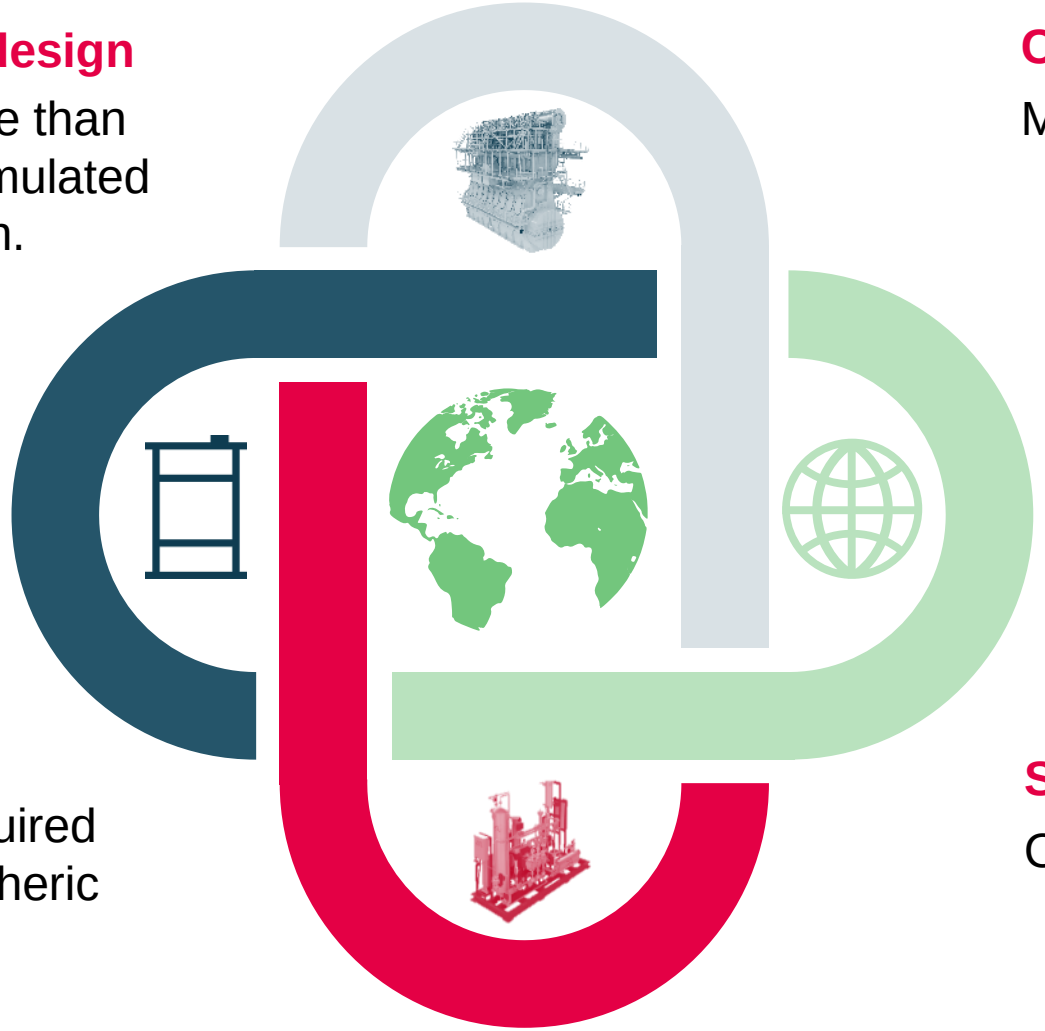
Why select methanol as marine fuel?

Proven MAN B&W engine design

In operation since 2016. More than 500.000 running hours accumulated on methanol alone since then.



Carbon neutral

Methanol can be carbon neutral.

Easy storage

No cryogenic equipment required and can be stored in atmospheric pressure tanks.

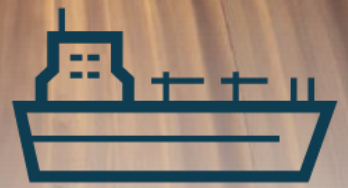
Simple fuel supply system

Only 13 bars required.

154 X MAN B&W ME-LGIM references

Methanol and product tankers
32 X 50-bore

Container vessels
70 X 95-bore
13 X 80-bore
23 X 50-bore

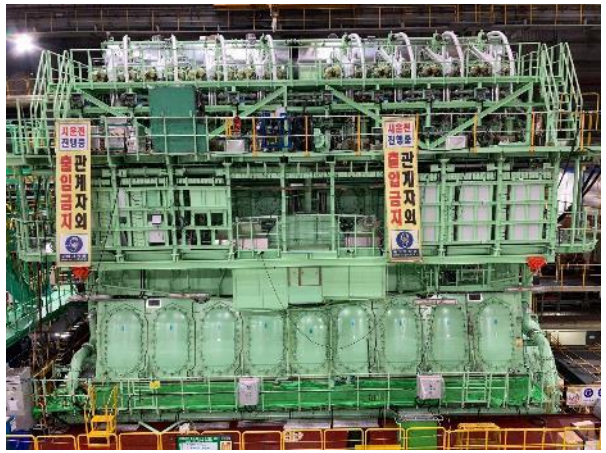


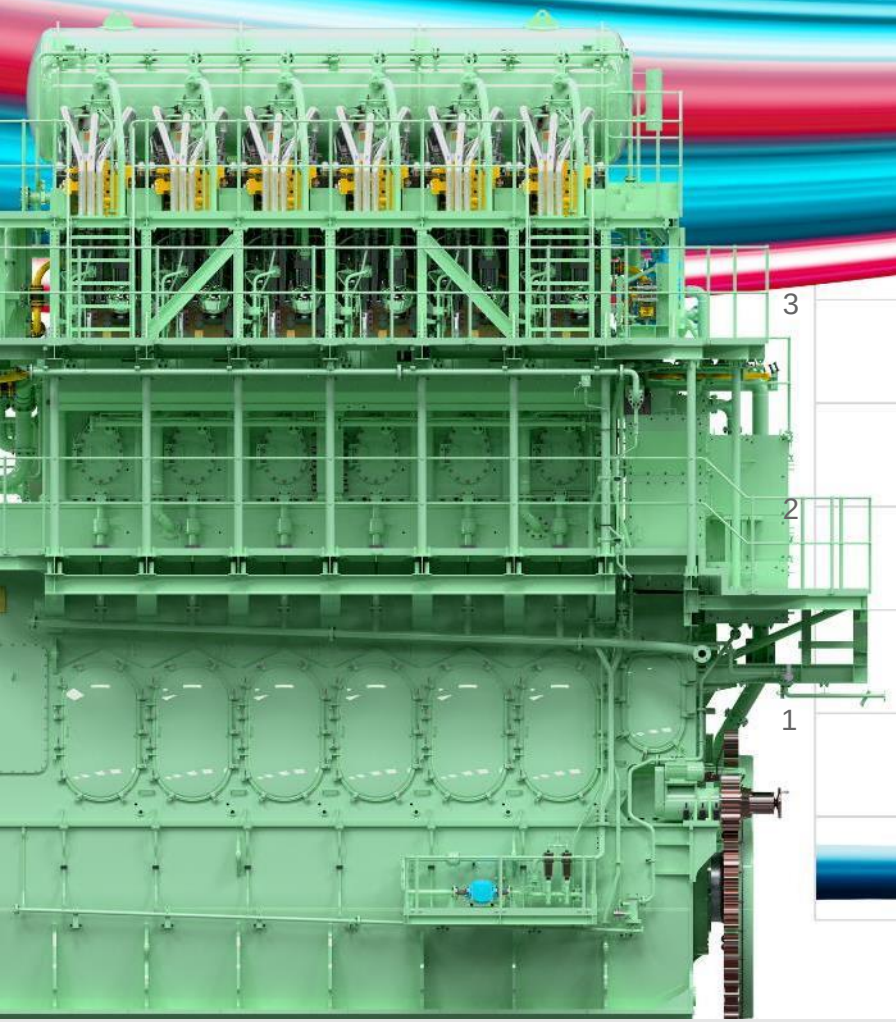
Bulk carriers
14 X 50-bore

PCTC
2 X 60-bore

First 8G95ME-C10.5-LGIM-EGRTC engine

March: 100% engine load on diesel oil. R&D test of liner, cover, exhaust and fuel valves. Methanol running end of march. **April:** 100% engine load on methanol and **F**actory **A**cceptance **T**est completed. Service Q1 2024.





Highest efficiency, lowest methane slip

MAN B&W ME-GI prepares your fleet for future regulations

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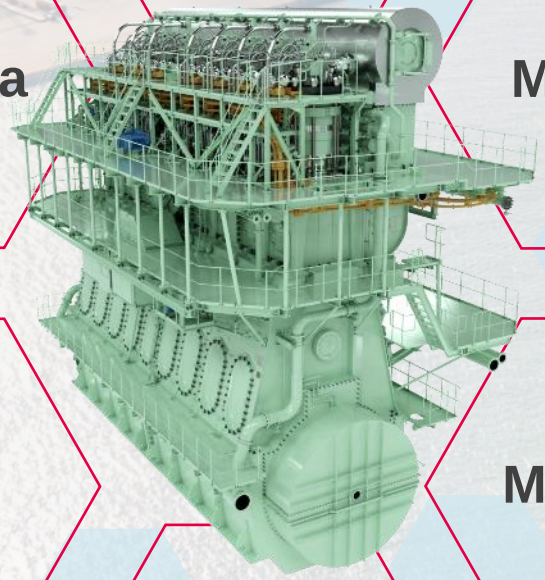
Modular design enables extensive retrofit options

Retrofit options

Ammonia

Methane



LPG

Methanol

Ethane

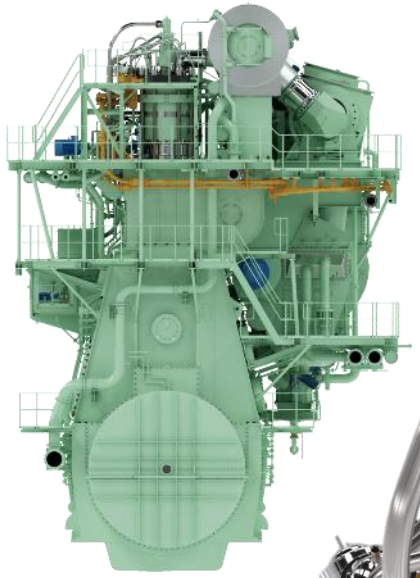
Retrofitting is a proven concept for MAN Energy Solutions engines

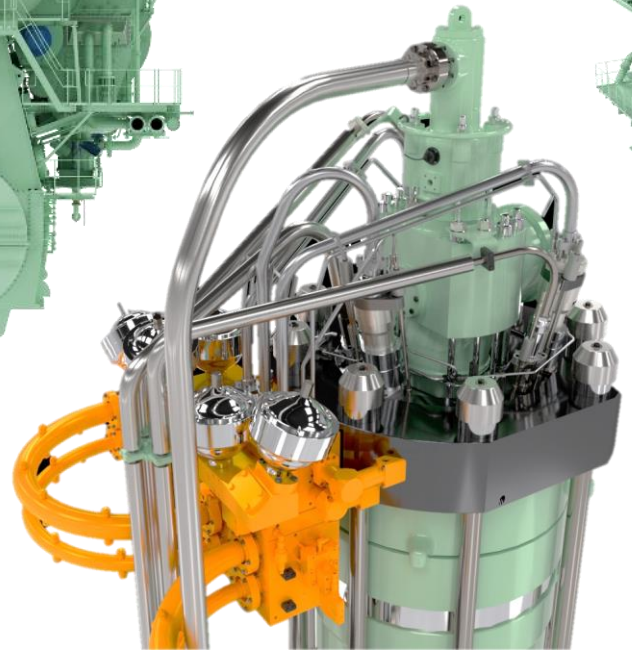
- ✓ 19 two-stroke engines retrofitted
- ✓ 4 four-stroke engines retrofitted

Retrofit scope related to auxiliary systems

Service tank

Low flashpoint fuel supply system





Fuel Valve Train

ME-LGIM ventilation

Nitrogen purging

Engineering	Production & transporation	Conversion / installation	Sea and gas trial
5 months Pending on final scope	9 months	1-2 months	¾ months

Two-stroke retrofit pipeline of contracted projects

Selected orders from 2023

Seaspan & Hapaq-Lloyd
15+45 X S90-LGIM

APM Maersk
11 X G95-LGIM

Matson
1 X S90-GI

Tianjin Southwest
2 X G60-LGIP

MAN Energy Solutions

Press release

Augsburg, July 6th, 2023

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Agreement for methanol main engine retrofit solutions signed

MAN PrimeServ to deliver engine retrofit solutions for Seaspan and Hapag-Lloyd vessels for dual-fuel propulsion

MAN Energy Solutions has signed a Conversion Commitment Agreement with Seaspan Corporation (Seaspan), a global leader in containership ownership and management in collaboration with Hapag-Lloyd, one of the leading global liner shipping companies. Under the terms of the Agreement, MAN PrimeServ, MAN Energy Solutions' after-sales division, will deliver 15 engine retrofit solutions for conversion of vessels powered by individual MAN B&W S90-type fuel-oil-powered engines from the Seaspan and Hapag-Lloyd fleets to dual-fuel ME-LGIM engines capable of running on green methanol. This Agreement includes 45 optional engine retrofit solutions. Each conversion can provide a CO_2 reduction of 50.000–70.000 Tonnes each year, when operating on green methanol.

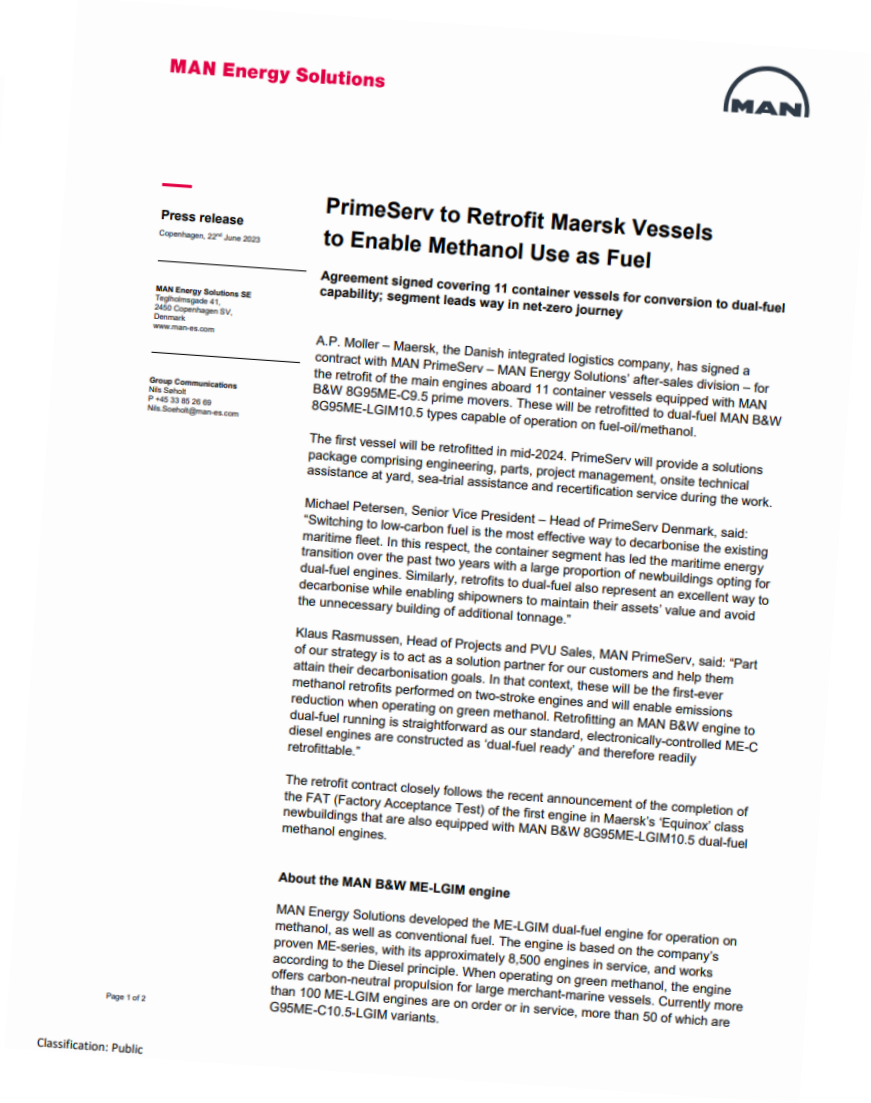
Bing Chen, President and Chief Executive Officer, and Torsten Pedersen, Chief Operating Officer, signed the Agreement on behalf of Seaspan, while Thomas Leander, Head of Solutions and Site Manager, Frederikshavn, Denmark; Jens Seeberg, Head of Retrofits & Upgrades, MAN PrimeServ Denmark; and Brian Østergaard Sørensen, Vice President and Head of R&D, Two-Stroke Business signed on behalf of MAN Energy Solutions. The development of this solution opportunity has been led by Thomas Leander of MAN Energy Solutions, Peter Curtis of Seaspan and Richard von Berlepsch, Managing Director Fleet of Hapag-Lloyd.

Seaspan is the largest global containership lessor, primarily focused on long-term time charters with the world's leading container shipping lines. With an industry-leading newbuild program of 70 vessels, Seaspan will bring its owned fleet to a total of 200 vessels and 1.9mn TEU capacity.

With a fleet of 250 modern container ships and a total transport capacity of 1.8 million TEU, Hapag-Lloyd is one of the world's leading liner shipping companies. Hapag-Lloyd aims at operating its vessels in a climate-neutral manner to become net-zero carbon by 2045.

Leander said: "Seaspan and Hapag-Lloyd, are significant maritime stakeholders with strong fleet-decarbonisation commitments and strategies. This Agreement shows clear intent to drive the industry transition toward zero-carbon shipping. Retrofitting existing engines to dual-fuel running is one of the most effective ways to reduce greenhouse gas emissions and to derive greater efficiency and profitability from an existing shipping fleet, while simultaneously delivering fuel flexibility and extending operational lifetimes. Crucially, this also avoids the unnecessary building of additional tonnage with associated CO_2 emissions, and thereby showcasing that retrofitting the existing maritime fleet is an important and feasible path.

With this collaborative agreement, we proceed our journey providing decarbonisation solutions for the maritime industry."



MAN Energy Solutions

Press release

Copenhagen, 22nd June 2023

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PrimeServ to Retrofit Maersk Vessels to Enable Methanol Use as Fuel

Agreement signed covering 11 container vessels for conversion to dual-fuel capability; segment leads way in net-zero journey

A.P. Moller – Maersk, the Danish integrated logistics company, has signed a contract with MAN PrimeServ – MAN Energy Solutions' after-sales division – for the retrofit of the main engines aboard 11 container vessels equipped with MAN B&W 8G95ME-C9.5 prime movers. These will be retrofitted to dual-fuel MAN B&W 8G95ME-LGIM10.5 types capable of operation on fuel-oil/methanol.

The first vessel will be retrofitted in mid-2024. PrimeServ will provide a solutions package comprising engineering, parts, project management, onsite technical assistance at yard, sea-trial assistance and recertification service during the work.

Michael Petersen, Senior Vice President – Head of PrimeServ Denmark, said: "Switching to low-carbon fuel is the most effective way to decarbonise the existing maritime fleet. In this respect, the container segment has led the maritime energy transition over the past two years with a large proportion of newbuildings opting for dual-fuel engines. Similarly, retrofits to dual-fuel also represent an excellent way to decarbonise while enabling shipowners to maintain their assets' value and avoid the unnecessary building of additional tonnage."

Klaus Rasmussen, Head of Projects and PVU Sales, MAN PrimeServ, said: "Part of our strategy is to act as a solution partner for our customers and help them attain their decarbonisation goals. In that context, these will be the first-ever methanol retrofits performed on two-stroke engines and will enable emissions reduction when operating on green methanol. Retrofitting an MAN B&W engine to dual-fuel running is straightforward as our standard, electronically-controlled ME-C diesel engines are constructed as 'dual-fuel ready' and therefore readily retrofittable."

The retrofit contract closely follows the recent announcement of the completion of the FAT (Factory Acceptance Test) of the first engine in Maersk's 'Equinox' class newbuildings that are also equipped with MAN B&W 8G95ME-LGIM10.5 dual-fuel methanol engines.

About the MAN B&W ME-LGIM engine

MAN Energy Solutions developed the ME-LGIM dual-fuel engine for operation on methanol, as well as conventional fuel. The engine is based on the company's proven ME-series, with its approximately 8,500 engines in service, and works according to the Diesel principle. When operating on green methanol, the engine offers carbon-neutral propulsion for large merchant-marine vessels. Currently more than 100 ME-LGIM engines are on order or in service, more than 50 of which are G95ME-C10.5-LGIM variants.

Page 1 of 2

Classification: Public

Agenda

1 Future fuel mix and IMO targets

2 Ammonia engine development update

3 Methanol & Methane engines

4 Retrofit

5 Summary

Summary

The technologies are ready!

- Methanol is now!
- MAN B&W ME-GI solves the problem of methane slip from TtW.
- Ammonia as a marine fuel is expected to pick up fast when positive seagoing experience has been achieved.
- There will not be a single clear winner among alternative fuels.
- IMO regulation require extensive retrofit of existing fleet as well as carbon-neutral newbuilds.
- Significant volumes of bio-methane, bio-methanol, blue-ammonia and green ammonia are needed to decarbonize shipping.
- Capital from carbon-tax should be used to invest in production of E-fuels.

Disclaimer

All data provided in this document is non-binding.
This data serves informational purposes only and is especially not guaranteed in any way.
Depending on the subsequent specific individual projects, the relevant data may be subject to changes and will be assessed and determined individually for each project. This will depend on the particular characteristics of each individual project, especially specific site and operational conditions.

MAN Energy Solutions
Future in the making

Thank you very much!

Næste oplæg

Kristen Kristensen,
Crossbridge Energy

Biogas Danmark

GREEN GAS DENMARK

2023

Crossbridge
ENERGY FREDERICIA

FORBRUG AF STORE MÆNGDER GRØN BRINT I DANMARK

Ved Kristen Kristensen, Front End Development Lead

Fakta

- Indviet 19. august 1966
- Shell-ejet indtil 30. juni 2021
- Ca. 270 medarbejdere
- Producerer ca. 35% af Danmarks forbrug af benzin, diesel, fuel, jet mv.
- 10.000 T/D
- 150-170 tankbiler transporterer dagligt produkter til Jylland/Fyn
- Vi håndterer al dansk rørlagt Nordsøolie
- Co-processing påbegyndt januar 2022
- Areal ca. 100 ha – svarende til ca. 180 fodboldbaner

Hvor er vi i dag?

Raffinaderiet har en stor samfundsmæssig påvirkning:

- 419.000 ton/år (Scope 1)
- 6,5 mio. ton/år (Scope 3)

Vi er i dag verdens 3.-mest energieffektive raffinaderi og nr. 1 i Europa

Vi er Danmarks største leverandør af overskudsvarme (ca. 23.000 alm. husstande)

Vi har en målsætning om at være CO2-neutrale i 2035

Vi har oprettet Strategic Growth Projects, der for nuværende arbejder med en lang række projekter

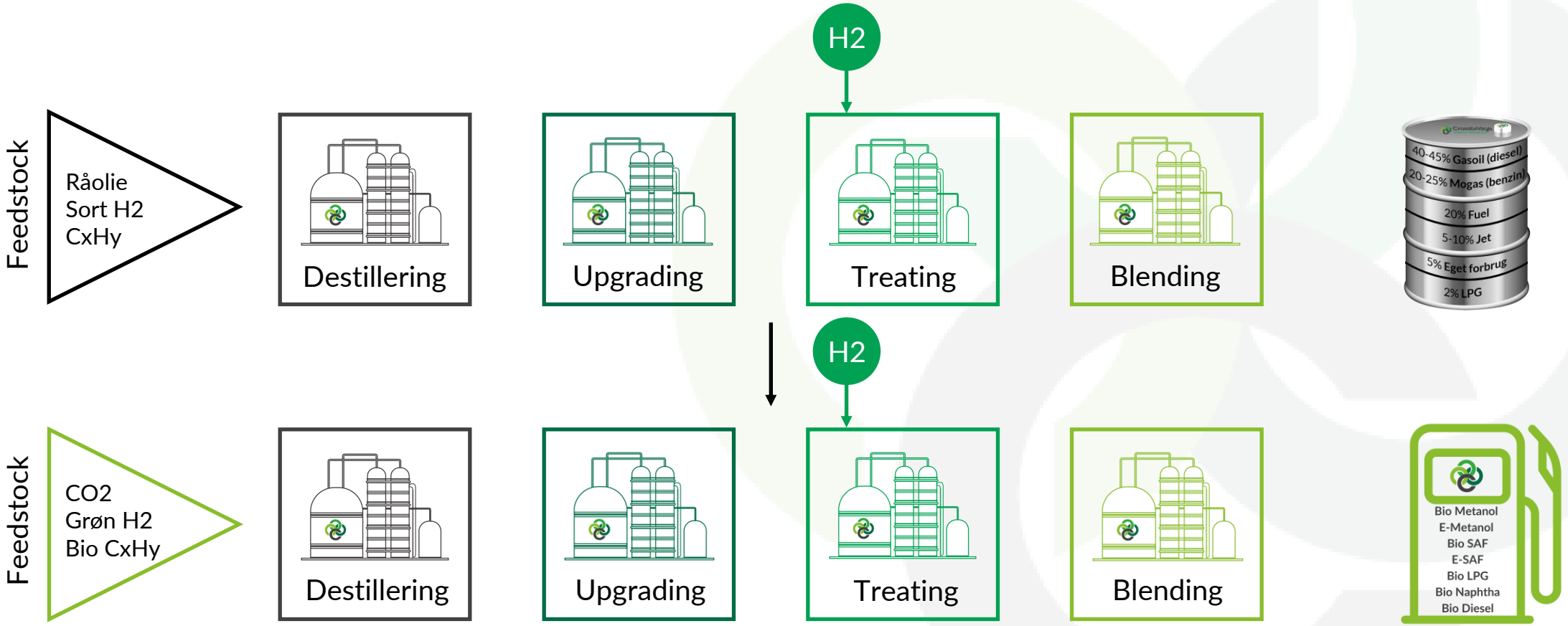
Crossbridge ENERGY FREDERICIA

Strategi i to spor

1 Vi fastholder og udbygger vores gode forretning indenfor fossile brændstoffer

2 Vi udvikler og skaber indtjening og vækst i vores grønne forretning

Raffinaderiprocesser – nu og i fremtiden



De tre spor i den grønne transformation

1 CO2 neutralisering af Crossbridge Energy Fredericia

2 Produktion af fremtidens grønne brændstoffer via nyt HDS anlæg

3 Produktion af fremtidens grønne brændstoffer med importeret grøn CO2

HySynergy

- HySynergy er et samarbejde mellem Everfuel og CBE omkring produktion grøn brint
- Det fælles projekt består af et brintanlæg (Everfuel) samt anvendelse af grøn brint (CBE)
- Projektet har tre faser:
  - Fase I 20 MW elektrolyseanlæg
  - Fase II op til 300 MW elektrolyseanlæg
  - Fase III 1 GW elektrolyseanlæg
- HySynergy har blandt modtaget IPCEI-midler og vundet Green Power Prisen 2023

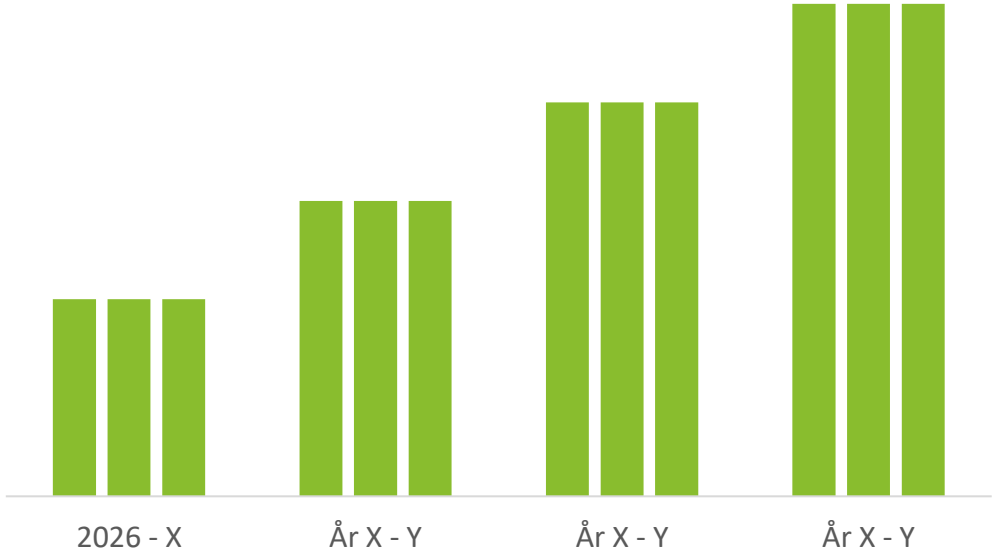
Udvikling i brintbehovet

Dagligt forbrug i dag: 35 ton fossilt brint

HySynergy phase 1
- Integrering i eksisterende fossile brændstoffe, samt Co-Refining af fornybare feedstocks

HySynergy phase: 2a
- Bio-brændstof produktion
HySynergy phase: 2b
- Erstatning af fossil brint produktion
HySynergy phase: 2c
- Produktion af e-fuels

Network - EnergiNet
- Kommerciel produktion af e-fuels



Brintinfrastrukturen er afgørende

- Crossbridge Energy bliver en af de største nationale aftagere af grøn brint
- Udrulningen fra Esbjerg til Fredericia skal prioriteres (Nedre T)
- Linjen skal gå til Fredericia Nord (Crossbridge/Everfuel)
- Der skal tages højde for et stødt stigende nationalt brintbehov
- Tilkobling på transmissionsniveau er at foretrække ud fra antagelsen om indførelse af differentierede tariffer
- Brintinfrastrukturen skal agere som bufferlager

Glem ikke kulstof (ikke udtømmende)

- Crossbridge Energy skal bruge enorme mængder biogent kulstof til at erstatte den fossile råolie (CO_2 el. biomasse)
- Stor udfordring at støttemidlerne på CO_2-området udelukkende tilgår CCS (særlig udfordring produktionen af e-fuels med dertilhørende EU-krav)
- Manglende udbygning af den nødvendige CO_2-infrastruktur
- Der er et stort behov for en europæisk certificeringsordning (Kommissionsudspil forventes i Q4)
- Der er behov for national regulering af CO_2-kvalitetskrav (hvor slutanvendelsen, hhv. CCU eller CCS, med de strengeste kvalitetskrav tilgodeses)

SPØRGSMÅL?

Næste oplæg

Rasmus Bernsdorf,
Eurowind

Biogas Danmark

GREEN GAS DENMARK

2023

PtX & Biogas

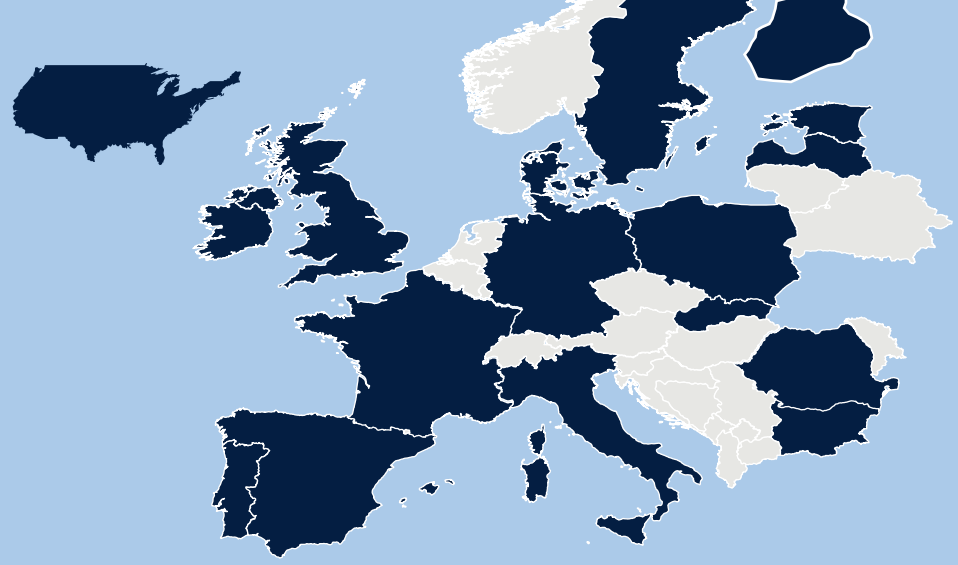
Rasmus Bernsdorf, Head of Biogas

Eurowind Energy™

EWE Holding ApS: **50%**

Norlys Holding A/S: **50%**

Eurowind Energy + NORLYS



Stiftet

2006

Grundlæggere
Jens Rasmussen
Søren Rasmussen
Jakob K. Kortbæk

Ansatte

450

Direktion
CEO Jens Rasmussen
CFO Søren Bæk Just

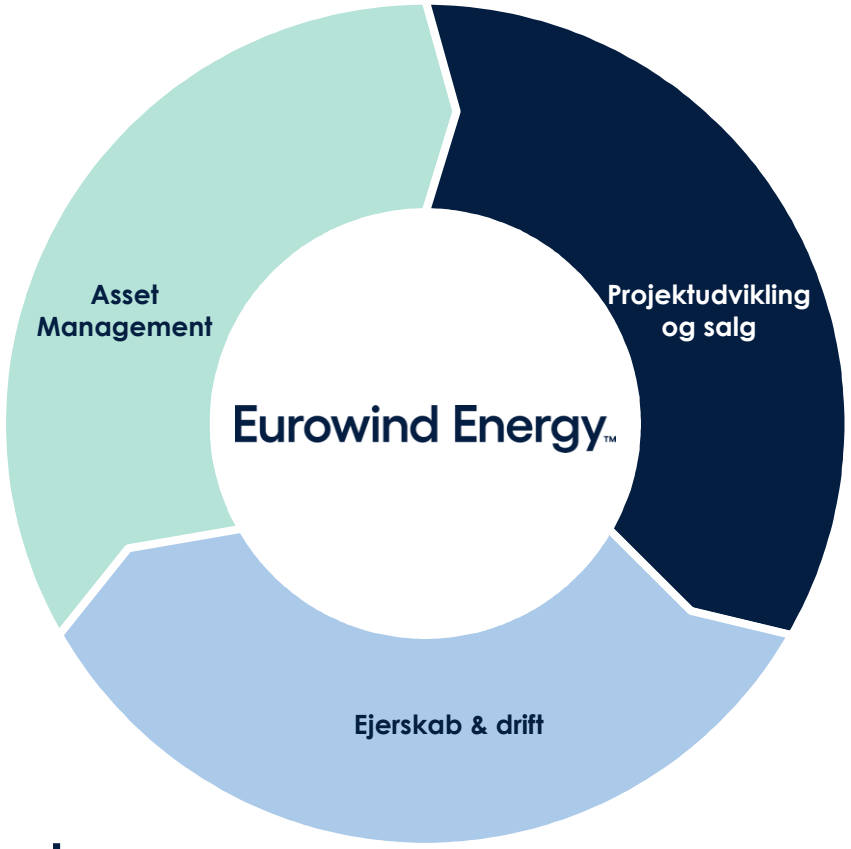
Lande

16

Hovedkontor
Mariagervej 58 B
9500 Hobro
Denmark

Overordnet strategi

Vi har **en balanceret forretning**, hvor tre forretningsområder understøtter hinanden.



Projekt-udvikling:

Vi vil være en førende europæisk udvikler af vedvarende energiprojekter

Ejerskab & drift:

Vi vil udbygge ejerskabet af MW i porteføljen og derved opbygge en energikoncern med produktion af strøm fra vedvarende energikilder

Asset Management:

Vi vil være en førende europæisk administrator af vind- og solprojekter

Eurowind Energy A/S i tal 2021 - 2022

1.294 mio. DKK
Omsætning

3.119 mio. DKK
Egenkapital

8 Biogas
Projekter under udvikling

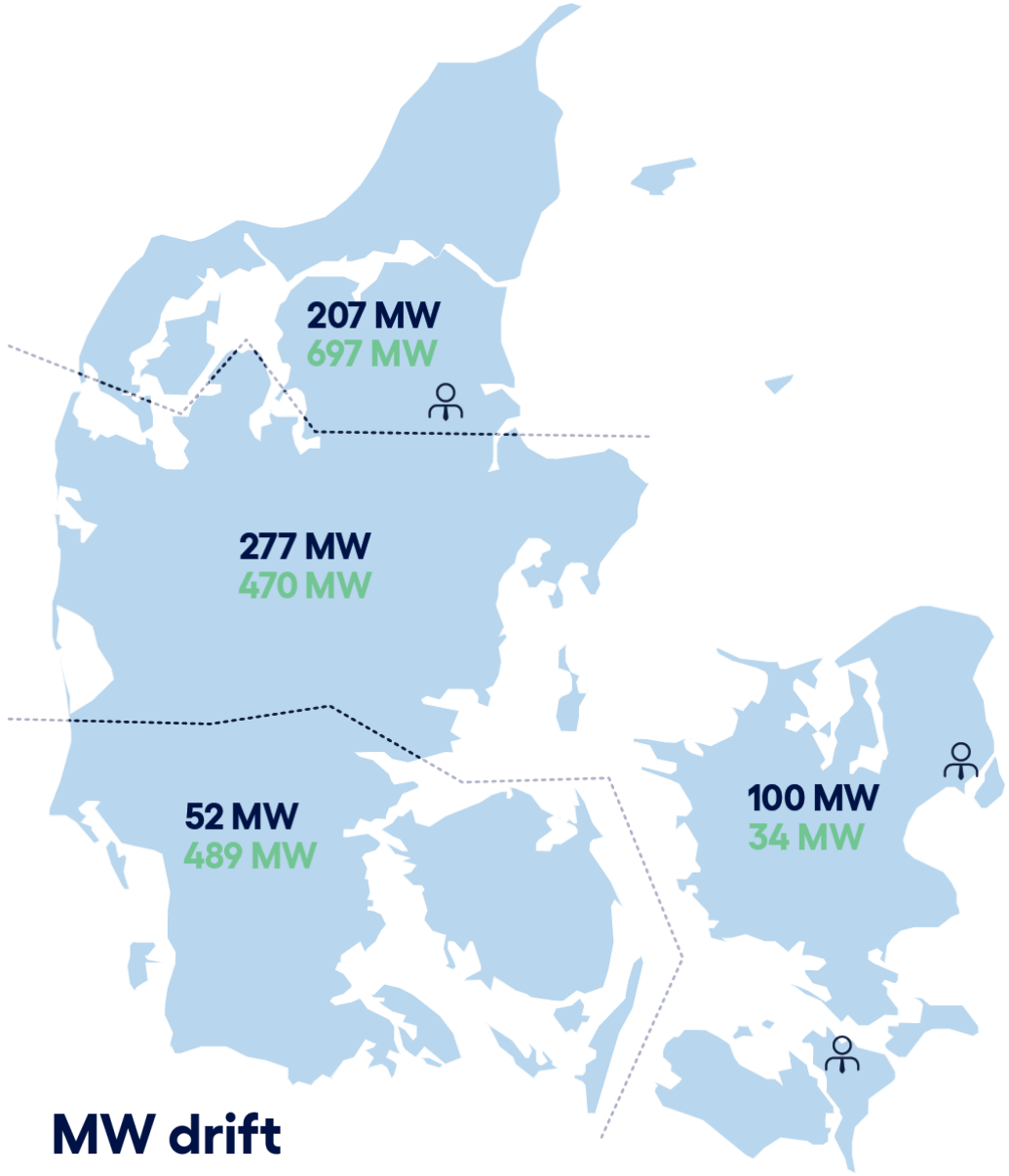
+ 10 PtX
Projekter under udvikling

+ 1 GW
Ejerskab - vind & sol

1.639 MW
Drift - vind & sol

5 Energicentre
under udvikling

Fjernvarme
Flere projekter på vej



MW drift
MW under udvikling
Kontorer

Eurowind Energy

Eurowind Energicenter

- Vindmøllre
- Solar PV
- Batteri
- Electrolyse
- Biogas
- E-fuels

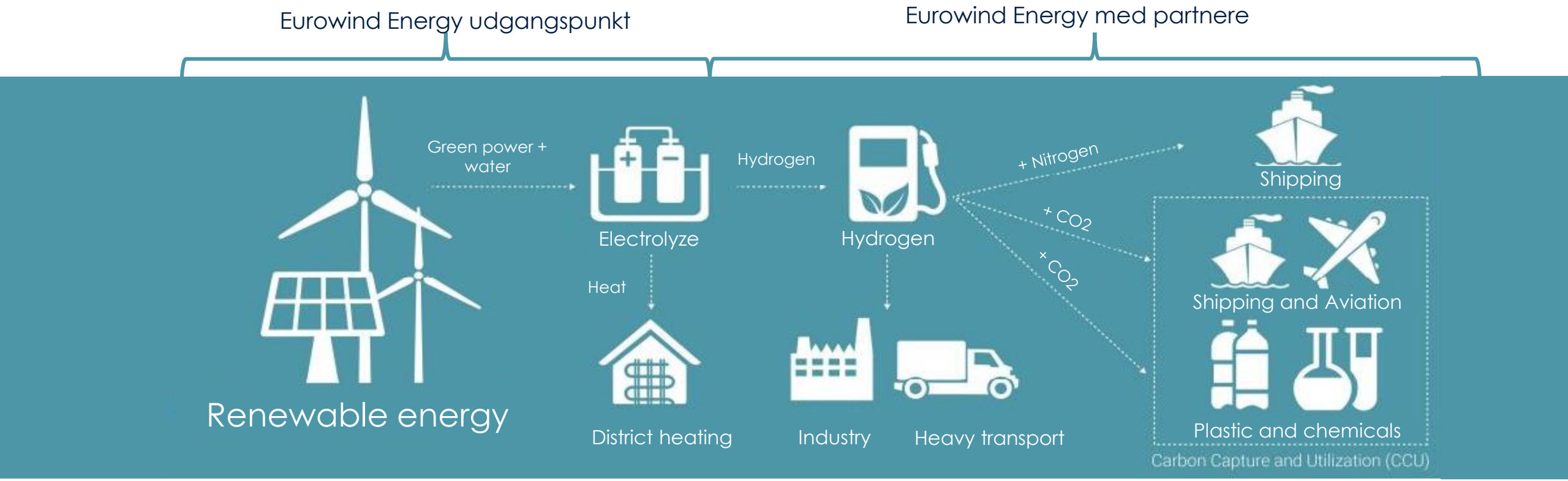
- Energipark Aalborg/Bolle Enge
- Nørrekær Enge II
- Overgaard
- Vollum Enge
- Gasse Hede

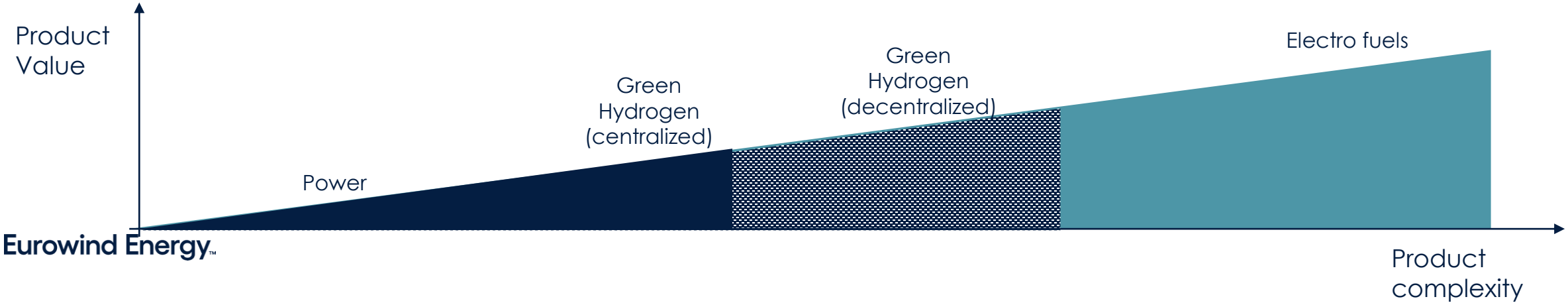
Samplacering er nøglen

Som udgangspunkt bliver Eurowind Energys biogasanlæg placeret sammen med strøm og hydrogen produktion

VISUALIZATION BY KIRTxTHOMSEN

Eurowind Energi på vej op gennem værdikæden. Fra "commodity" til produkter med merværdi





Spørgsmål?

Eurowind Energy™

Eurowind Energy™

Pause til kl. 16.25

Kaffe, netværk og udstillingsboder

Biogas Danmark

GREEN GAS DENMARK

2023