
# Hydrogen technologies:
# Equinor technology initiatives and projects

International CCUS and Hydrogen symposium – Tokyo
20 February 2020

# Agenda

- Introduction to Equinor
- Our strategic response to climate change
- Understanding the challenge of deep decarbonisation
- CCS and hydrogen as building blocks in our strategy

# Introduction to Equinor

# We are Equinor

OUR PURPOSE

Turning natural resources into energy for people and progress for society

OUR VISION

Shaping the future of energy

OUR STRATEGY

Always safe,
High value,
Low carbon

# Facts and figures 2018

## 18.0

**Billion USD**
adjusted earnings as of Q4 2018

## 2.11

**Million barrels**
of oil equivalent per day

## 1 mill

**European homes**
through growing offshore wind power business

## ~40

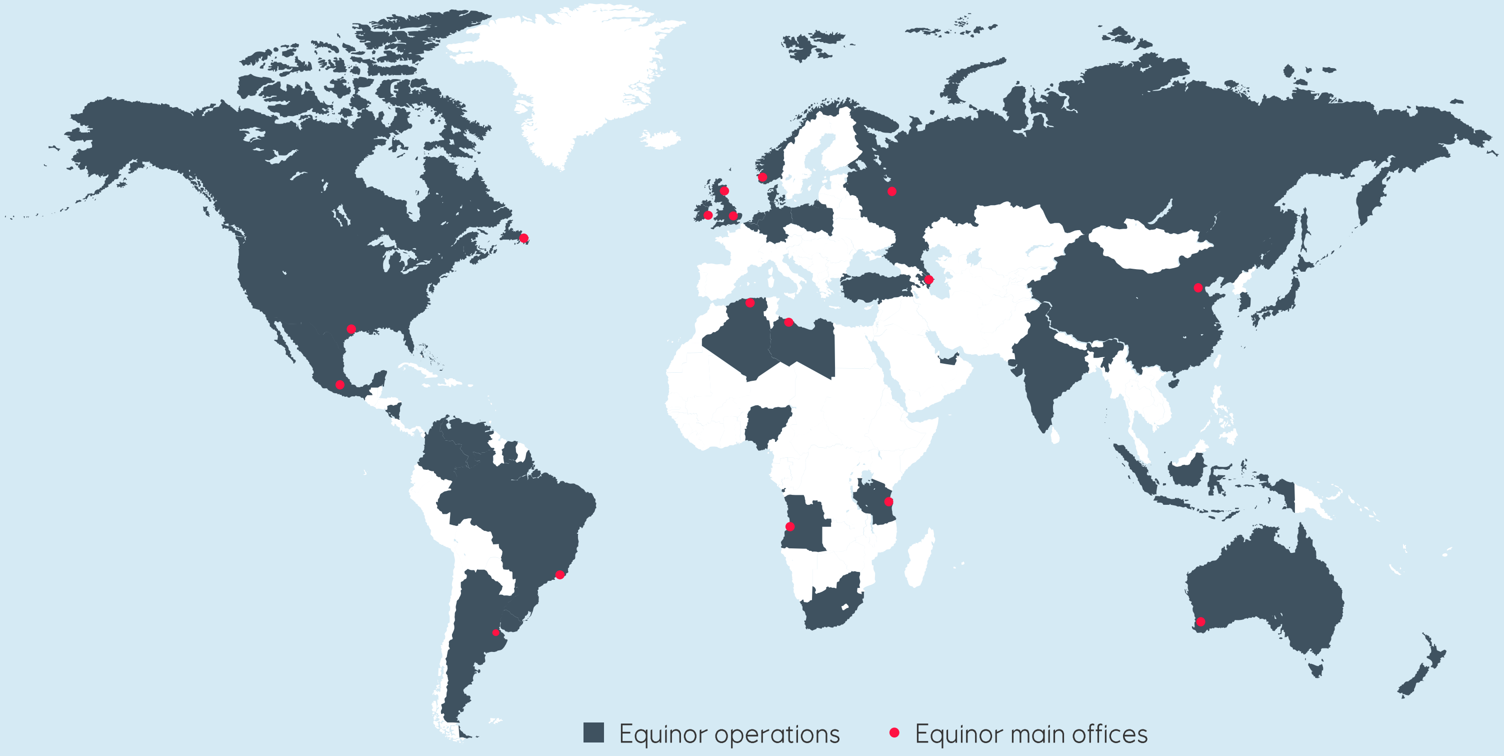
**Percent**
of oil and gas production outside Norway

## >20.000

**Employees**

## >30

**Countries**



# Equinor´s strategic response to climate change

Our climate roadmap

# A strategy to create a low-carbon advantage

### Reduce emissions from operations

$CO_2$ emission reductions of 5 million tonnes per year by 2030 [1]

Upstream portfolio carbon intensity of 8kg $CO_2$ /boe in 2030

Maintain very low methane intensity (0.03%)

### Grow in new energy solutions

Renewable energy and low carbon solutions

We expect around 15-20% of our investments to be in new energy solutions in 2030 [2]

Up to 25% of research funds to new energy solutions and energy efficiency by 2020

### Climate embedded in decision making

Carbon price

Portfolio stress-testing

Transparent reporting

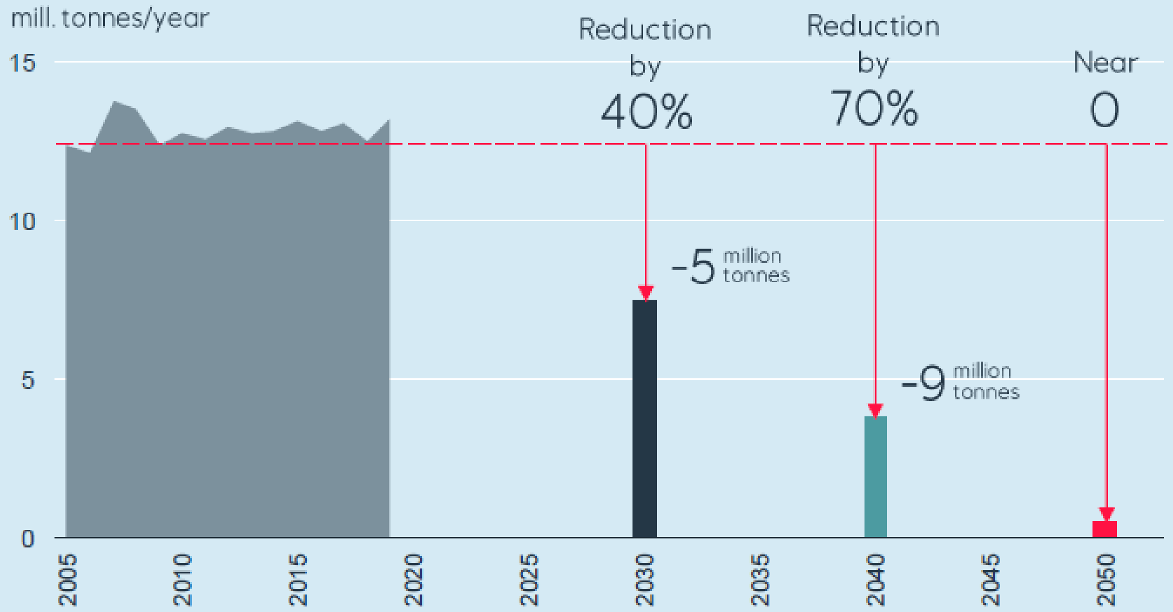
Climate part of strategy, decision-making and incentives

1. We aim to achieve, by 2030, annual $CO_2$ emissions that are 5 million tonnes less than they would have been, had no reduction measures been implemented between 2017 and 2030
2. Assuming we can access and mature profitable projects.

New climate ambitions for our activity in Norway

## Annual greenhouse gas emissions

Equinor operated onshore facilities and offshore fields




## Continued significant value creation for the company and society

- Potential to generate around NOK 3.000 billion in income for the Norwegian State towards 2030[1]

## Large scale industrial measures

- Investments NOK ~50 billion[2]
- Operational measures and energy efficiency
- Electrification
- Consolidation of infrastructure
- Zero-emission design for new fields
- New value chains

1. Accumulated tax income and cash flow from Petoro, from Equinor operated fields and facilities 100% basis.
2. Equinor operated fields and facilities 100% basis. Subject to investment decisions in the licenses.

# Building a portfolio with new energy solutions

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## Offshore wind

### In production


1,130 MW

### Project pipeline


~10,000 MW*

### Floating


30 MW

Market Potential 2030: 12 GW

## Onshore wind & solar

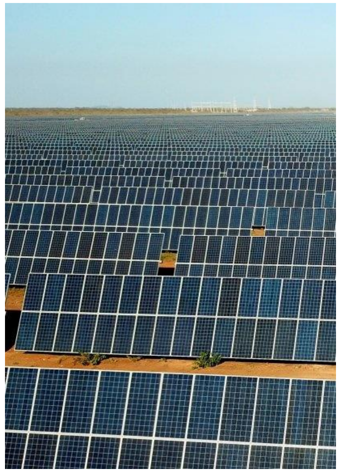
### In production


162 MW

### Pipeline

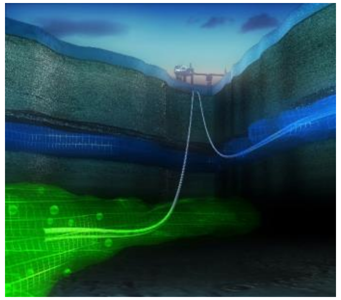

479 MW (solar)

120 MW (wind)

### M&A


10% stake Scatec

## Low carbon solutions

### CCS


### Hydrogen


### Hywind Tampen


## Trading

### Danske Commodities


Open

# Understanding the challenge of deep decarbonisation

# Decarbonising Energy Systems

Easy ⟵ complexity to decarbonise ⟶ Hard

**Transport**

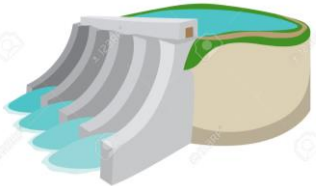
Battery (mostly) plus Hydrogen for Heavy Duty

Hydrogen Fuel-Cell Trains

Liquid Hydrogen/Ammonia and Fuel-Cells/Gas Engines for long haul Big Ships

**Power**

Large Battery Systems for Daily Swing (night-to-day)



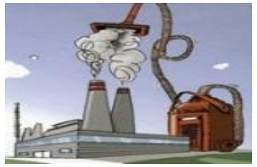
Hydro-Power as Battery for Small Scale Intermittency

Hydrogen fired CCGTs Clean Back-Up Power for Large Scale Intermittency

**Industry**

Light Industry powered by Renewable

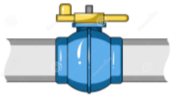
Heavy Industry powered by Hydrogen from Natural Gas + CCS



CCS for Industry without other Alternatives

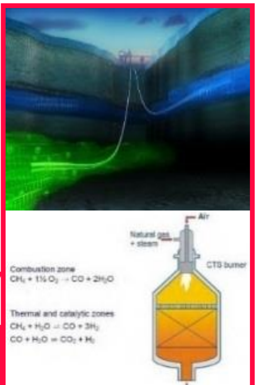
**Heat**

Heat Pumps For Efficient Use of Electricity in Homes



Hydrogen for Efficient Transfer of Energy from Production to End-Users


Hydrogen for Large Scale Seasonal Storage



**Natural Gas Reforming to Hydrogen with CCS**

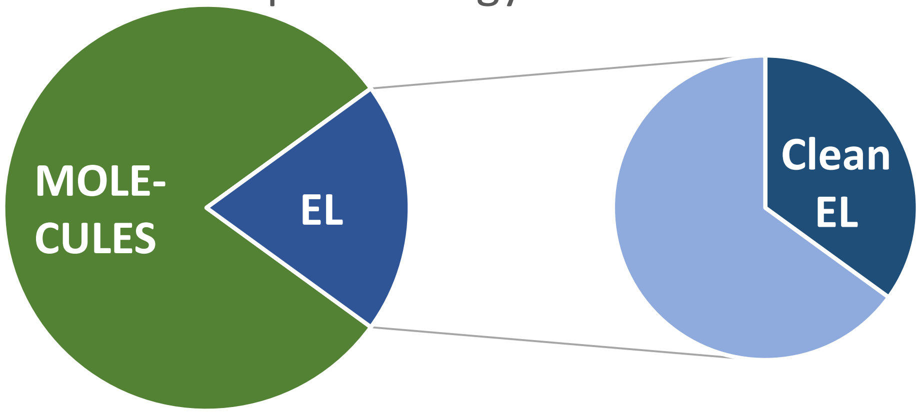
*Multiple technologies to address the challenge*

# Deep de-carbonizing: The Challenge and the Tool-Box

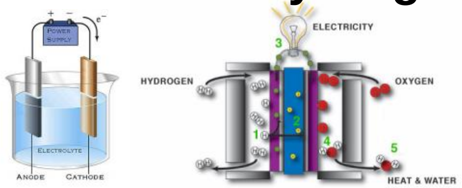

**Cost Efficiency EL : MOL**

Energy Transport 1 : 10
Long Term Storage 1 : 100

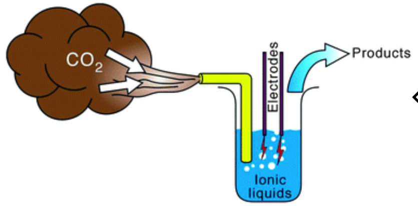
European Energy-Mix **2018**




## Green Hydrogen and Power to X



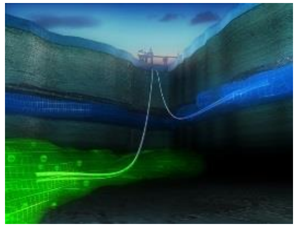

Electrolyser and Fuel Cell



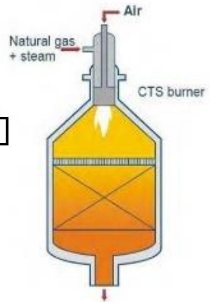

## CCS

## Blue Hydrogen

Hard-to-Decarbonize Industry

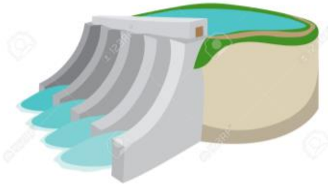


Permanent CO2 Storage (CCS)

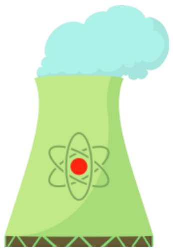



Gas Reformer w/CCS

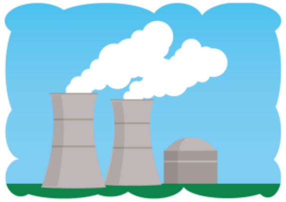
## Renewable EL



## Zero Carbon EL



Nuclear



Hydrogen fired EL power

## Improve Carbon Efficiency

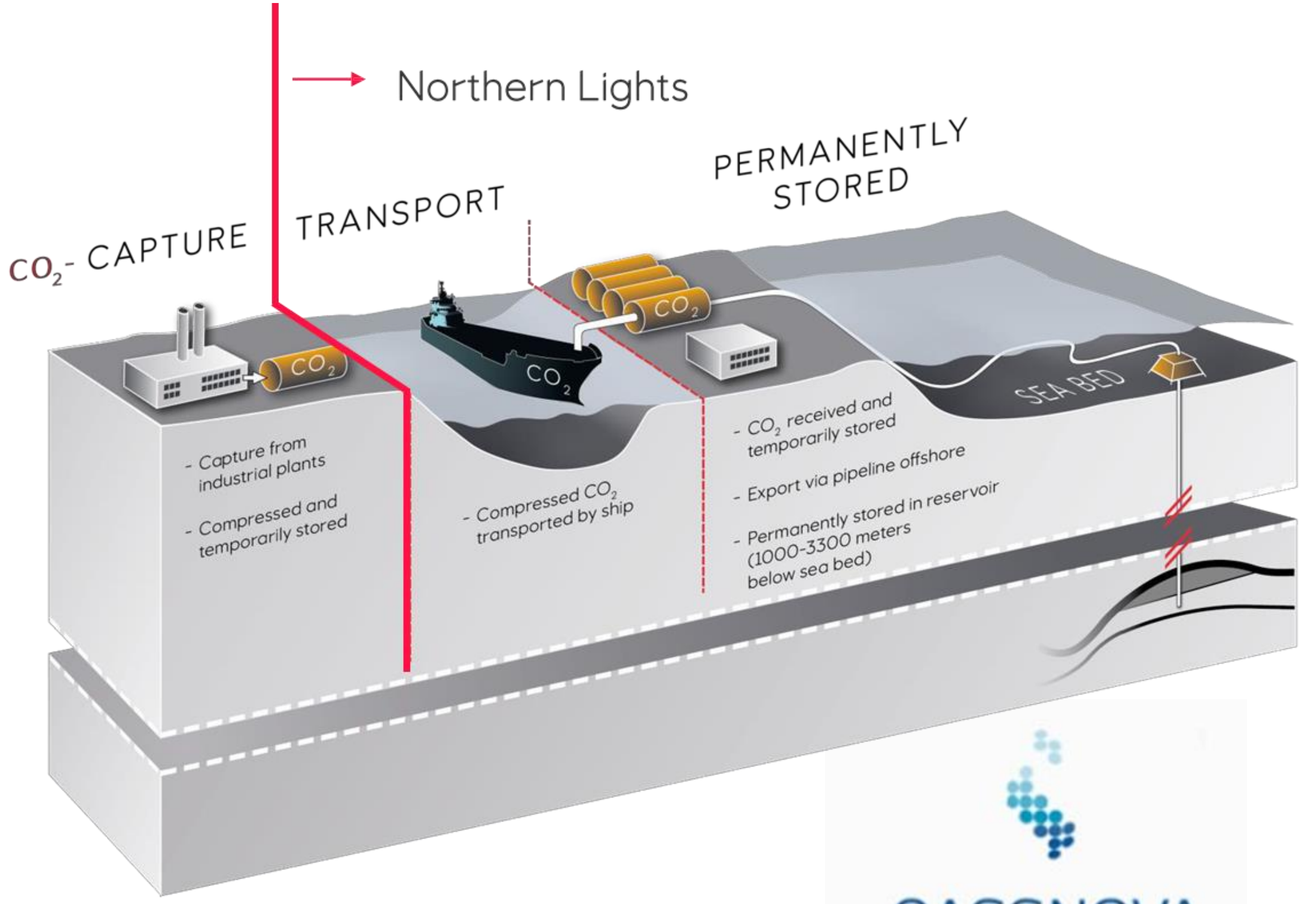
Switch from Coal …

… to Natural Gas

# CCS and hydrogen as building blocks in our strategy

# A European “open source” network for CO2 removal


Source: Bellona Europe




GASSNOVA

equinor

TOTAL

# NORTHERN LIGHTS CONCEPT OVERVIEW

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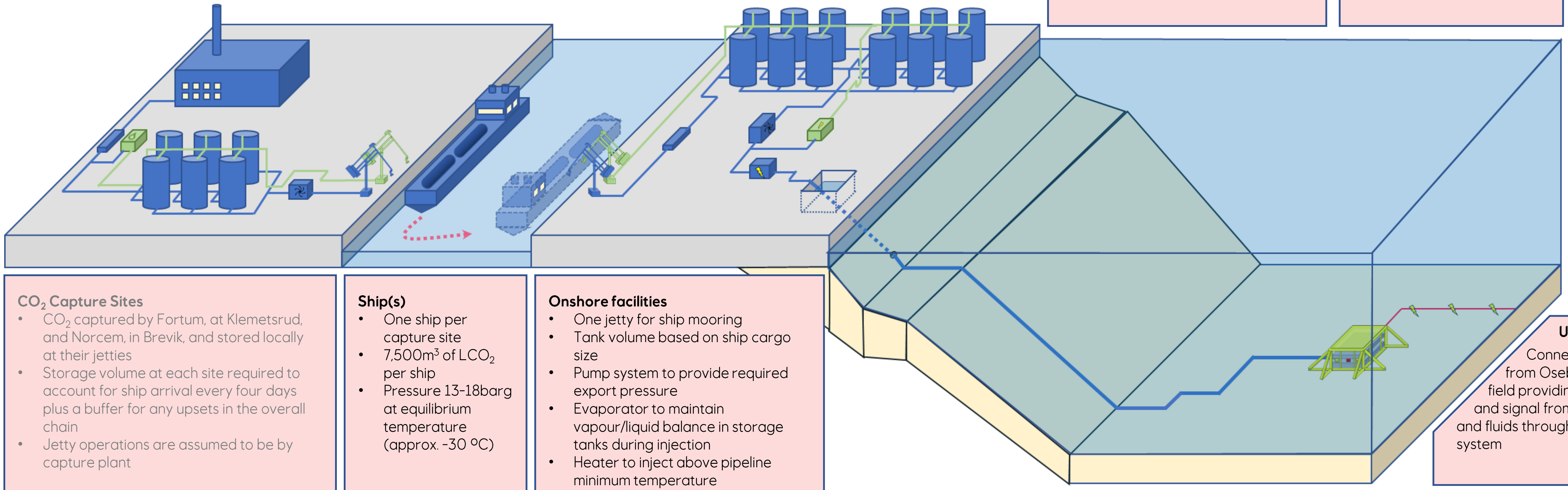
**Pipeline**
- 110km un-insulated pipeline
- 12 ¼ inch
- Single phase (liquid) $CO_2$

**Subsea facilities**
- Connecting pipeline, umbilical and well(s)
- Water depth ~300m
- Connection for future step-out

**Subsea injection well**
- Injection of $CO_2$ into reservoir at ~2-3000m depth
- Pressure in reservoir ~2-300bar
- Temperature in reservoir ~100 ºC



**$CO_2$ Capture Sites**
- $CO_2$ captured by Fortum, at Klemetsrud, and Norcem, in Brevik, and stored locally at their jetties
- Storage volume at each site required to account for ship arrival every four days plus a buffer for any upsets in the overall chain
- Jetty operations are assumed to be by capture plant

**Ship(s)**
- One ship per capture site
- 7,500m³ of $LCO_2$ per ship
- Pressure 13-18barg at equilibrium temperature (approx. -30 ºC)

**Onshore facilities**
- One jetty for ship mooring
- Tank volume based on ship cargo size
- Pump system to provide required export pressure
- Evaporator to maintain vapour/liquid balance in storage tanks during injection
- Heater to inject above pipeline minimum temperature

**Umbilical**

Connection from Oseberg-field providing power and signal from DC/FO and fluids through umbilical system

5 **Capacity (Mt/y)**

1.5

+ ship(s)

+ pump capacity
+ heater capacity
+ jetty
+ tanks?

+ well(s)

Capture Site 2
Capture Site 1

2 x ship
1 x ship

Onshore facilities

Pipeline

1 x injection well (tbc)

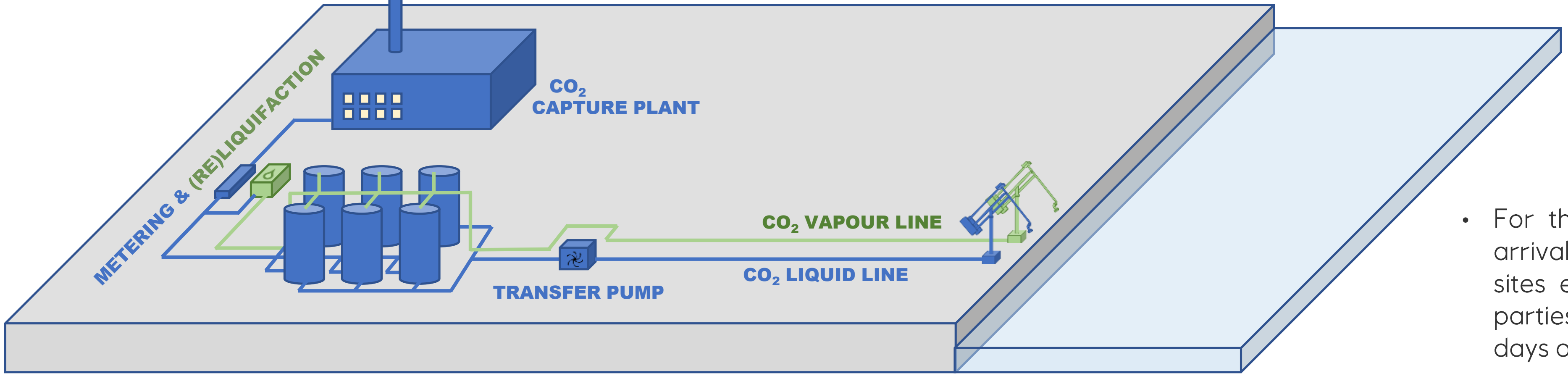
Umbilical system

**Storage complex**
- Planned in the Johansen formation south of Troll ("Aurora") with an expected capacity of at least 100 Mt of $CO_2$

# Indicative equipment requirements at capture sites

**Metering System**
- $CO_2$ Specifications are strict to avoid issues later in the chain
- Important to control pollutants in the $CO_2$ stream (e.g. water and chloride content to list some)

**(Re)Liquification system**
- Liquid $CO_2$ is stored in an equilibrium state. Due to heat ingress from the environment some of the liquid $CO_2$ will vaporise and lead to a pressure increase in the storage tanks
- This can either be vented or re-liquified and returned to the tanks



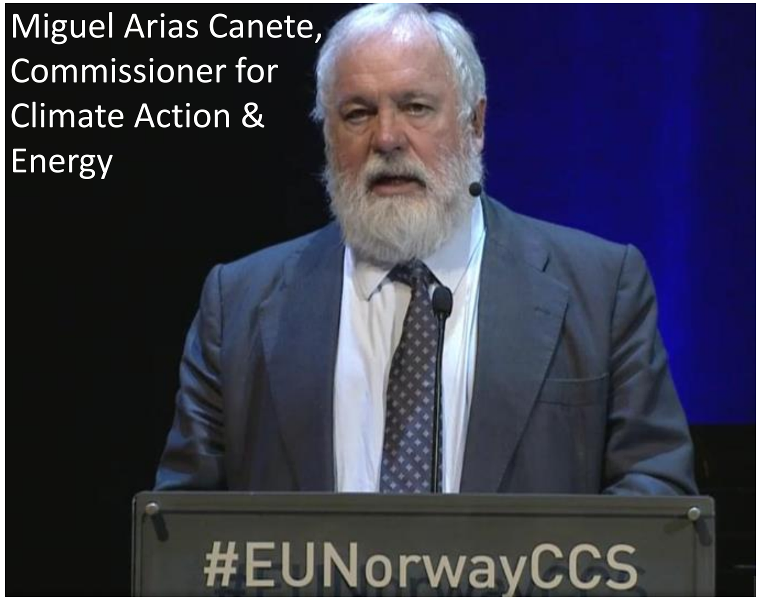

**Liquid $CO_2$ storage tanks**
- Cylindrical vertical/horizontal design
- Low Temperature Carbon Steel
- European Design Code (EN 13445)
- Capacity limited to ~750m$^3$ per tank to avoid Post-Weld Heat Treatment
- CO2 stored at 15 barg and equivalent equilibrium temperature

**$CO_2$ Transfer pump**
- Standard industry pumps available
- Widely used in the food industry
- Relatively low pressure-lift required; only to transfer $CO_2$ to from tanks to ship

**$CO_2$ Loading Systems**
- Loading arms or Hoses can be utilized
- Dependent on required loading rate as well as manning requirements
- Similarities with existing industry solutions (Food-grade $CO_2$ / LNG / LPG)

- The capture plant requires storage volume to cover time between ship arrivals plus a buffer to cover unplanned delays in the overall chain
  - As $CO_2$ is stored in equilibrium (with a liquid- and a vapour-phase) two transfer lines are used so the ship and storage tanks can exchange liquid for vapour in a one-to-one volume exchange
- For the Northern Lights Projects ship arrivals are planned at the capture sites every four days, i.e. the capture parties need to be able to store four days of captured $CO_2$
- Jetty operations are assumed to be by capture plant

# #EUNorway CCS




*"CCS is an absolutely necessary part of the solution. Norway's leadership is needed. Northern Lights among the most promising flagships that we need …"*

**Seven MoU's signed**

- Fortum Group; Finland
- Ervia, Ireland
- Air Liquide, Belgium
- Stockholm Exergi, Sweden
- ArcelorMittal, Luxembourg
- Preem, Sweden
- Heidelberg Cement Group, Germany

# Hydrogen technology business development

### H2M - Magnum

- Energy: 8-12 TWh
- Utilise existing gas power plants
- Switch fuel from natural gas to clean H2
- Clean electricity
- Clean back-up for solar and wind
- Launch large-scale H2 economy
- Partners: Vattenfall (Nuon) and Gasunie


### H21 North of England

- Energy: 75-85 TWh
- Domestic heating in UK
- Utilise existing gas network
- Synergies with industry/power generation
- Enables H2 to transport later
- Partners: Northern Gas Network and Cadent


### New Projects

- Maritime transport – Norway
- Clean Hydrogen Pilot - Norway
- Hydrogen for steel – Germany, with ThyssenKrupp and OGE

# Addressing the heavy transport sector

Liquid H2 value chain JIP

- Equinor and partners aim to make liquid hydrogen available for commercial shipping within the first quarter of 2024
- Adressing entire value chain: Production, distribution, terminals and end users
- Pilot-e supported (~30 MNOK)
- Partners: BKK, Air Liquide, Norled, Viking, NorSeaGroup, Gexcon, Norce and NCE Maritime cleantech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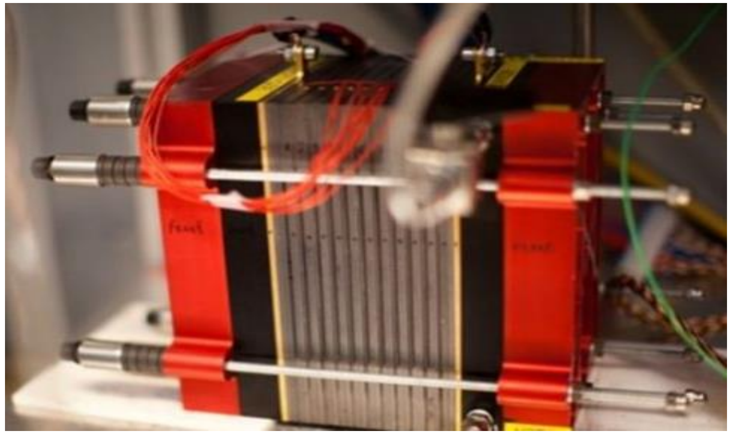
# ShipFC: Piloting Multi MW Ammonia Ship Fuel Cells

ShipFC



- **Objective:** Develop, test and pilot a 2 MW fuel cell (SOFC) system on ammonia
- **Demo** (Viking Energy): commercial operation for at least 3000 hours during a one-year period (2024). Covering at least 70% of total energy need with ammonia
- **Partners**: Equinor, Eidesvik, Wartsila, Prototech, Maritime cleantech, Yara, Strathclyde, Fraunhofer, Demokritos, North Sea Shipping, Capital Executive Ship Management, Star Bulk Shipmanagement, PersEE
- **Budget:** 230 MNOK total, 10 MEUR EU support

# Hydrogen to Steel ThyssenKrupp, Europe

## 2018
## The world premiere

The concept: $CO_2$ becomes raw materials. In September 2018, thyssenkrupp produced ammonia from steel mill gases for the first time at its Carbon2Chem® technical center in Duisburg.

## From 2019
## The test

Thyssenkrupp will gradually replace pulverized coal in one blast furnace (BF) with hydrogen ($H_2$).

## From 2020
## The industrialization

The pilot system at the Duisburg steel plant will use steel mill gases to produce base chemicals.

## From 2022
## The introduction phase

Step by step, all three blast furnaces (BF) will be transitioned to H2 injection.

## From 2024
## The milestone

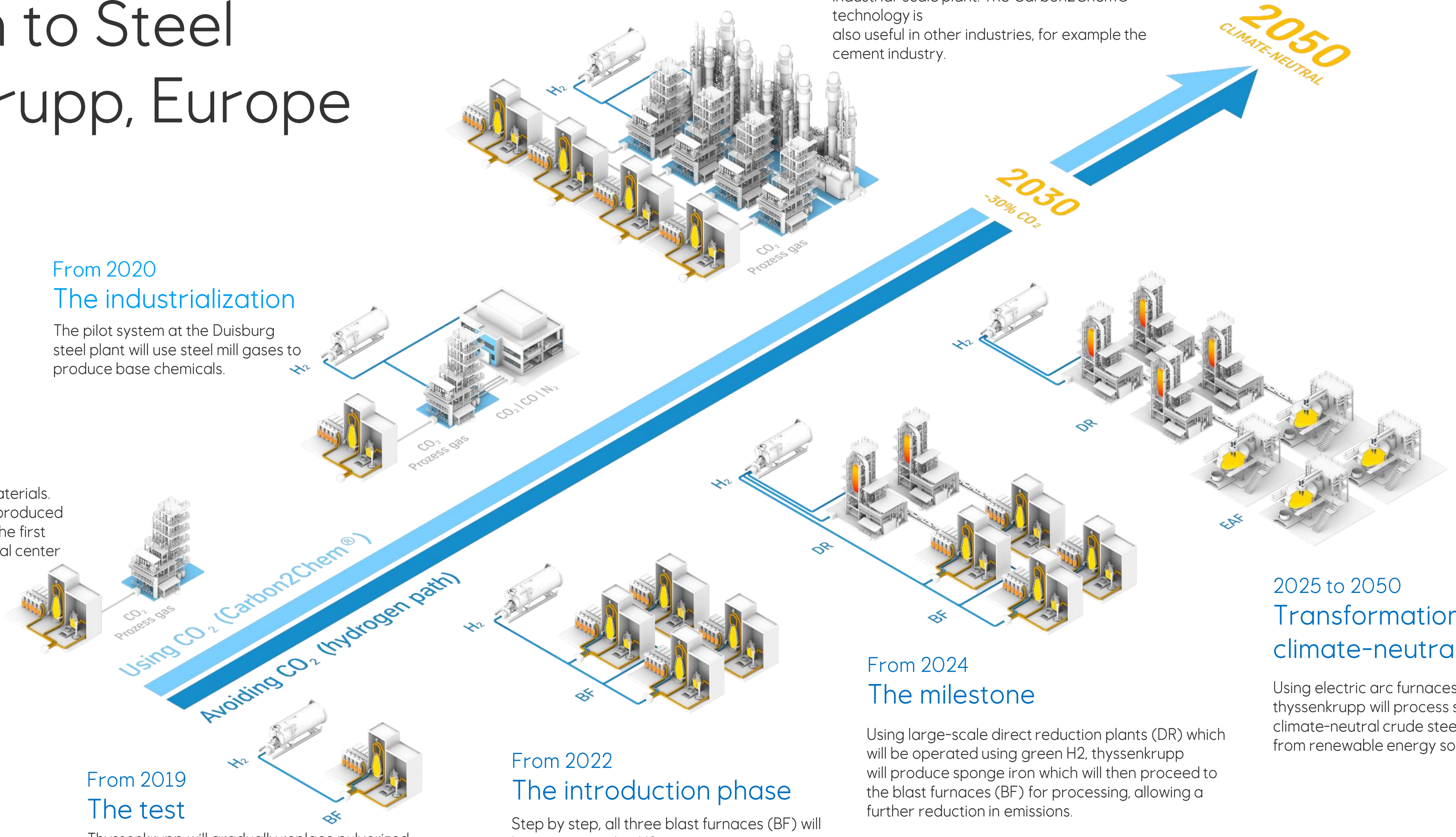
Using large-scale direct reduction plants (DR) which will be operated using green H2, thyssenkrupp will produce sponge iron which will then proceed to the blast furnaces (BF) for processing, allowing a further reduction in emissions.

## From 2025
## The breakthrough

$CO_2$ will be used as a raw material in an industrial-scale plant. The Carbon2Chem® technology is
also useful in other industries, for example the cement industry.

## 2025 to 2050
## Transformation into a climate-neutral steel mill

Using electric arc furnaces (EAF), thyssenkrupp will process sponge iron into climate-neutral crude steel using electricity from renewable energy sources.



# Hydrogen technology research and development

## Clean Hydrogen Production

- Novel reactor concepts
- Ammonia cracking
- Power for reforming


## Hydrogen Storage & Transport

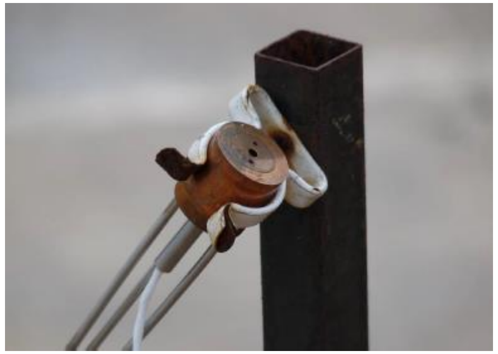
- $H_2$ liquefaction fundamentals
- New standards for pipelines
- $H_2$ material technology


## New Hydrogen Value Chains

- Large liquid $H_2$ and liquid $CO_2$ carriers
- Ammonia as $H_2$ carrier
- Organic $H_2$ carriers

## Hydrogen to Power

- Combustor and gas turbine testing
- Fuel cells
- Ammonia fueled gas engines



## Safety and trust in hydrogen

- Risk reduction by use and validation of risk analysis tools
- Combustion and explosion experiments

# Roadmap towards a commercial large scale hydrogen value chain

## From Technology Demonstration and Market Build to Large Scale Implementation

**2023**

**Northern Light**


$CO_2$ storage infrastructure

**2024/25**

**$H_2$ Value Chain demos**

Clean hydrogen value chain demonstration(s)

**2024**

**Transport: Maritime Fuel**

Hydrogen/ammonia for marine propulsion

**2024**

**Hydrogen (green) as REN Storage**

Hydrogen as renewable energy storage

**2027**

**Power: Magnum**

Hydrogen for power generation with CCS

**2028**

**Clean Steel**

Hydrogen for industry (steel)

**2029**

**Heat/Power/Industry: H21**

Hydrogen to heat & power

**2030+**

**Power/Industry: $H_2$ to Japan**

Global hydrogen supply chain

**Large Scale Implementation**

**Market build**

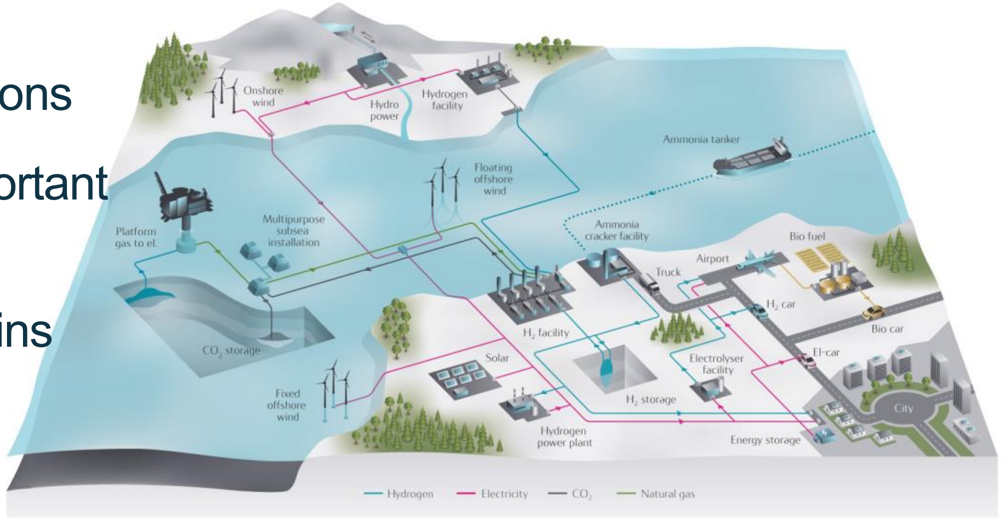
**Value Chain Demonstration**

# Commercial efforts need to be supported by right regulatory frames

- Create level playing field through carbon pricing and long-term roadmap for increase of carbon pricing
- Support R&D and first generation projects through grants and direct subsidies
- Consider quotas to support market growth
- FiT or similar price supporting/certain income mechanisms have proven succesfull to build renewable markets
- Adapt technical regulations to new energy carriers


# Key Messages

- Global decarbonisation towards 2050 a major challenge
- Renewable solutions critical for the energy transition
- Heavy industry, heat- and flexible power require large-scale solutions
- Within Equinor’s low carbon strategy, CCS and SMR play an important role as enabler of deep decarbonisation at scale and with pace
- Equinor supports the development of technologies and value chains
- Policy frameworks that ensure a level playing field and incentive structures are necessary to realise the energy transition




=> Clean gas/hydrogen essential to the decarbonization of the energy system