PCC IM-PACT 2022

POLIT CASE COMPETITION

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Introduction

Europe in crisis

Europe is facing an energy and climate crisis. There is an acute need to secure Europe's energy independence, mitigate climate change to meet the Paris Agreement, and keep the global temperature increase below 1.5°C. The solutions to these challenges are the same: replace fossil fuels with renewable energy, directly and indirectly electrify energy use, and increase energy efficiency.

Following Russia's recent invasion of Ukraine, the task has become significantly more pressing. According to the International Energy Agency (IEA), Russia is the world's largest oil exporter to global markets, and its natural gas fuels the European economy, accounting for approximately 40% of the EU's gas consumption. The EU is already a leader in the build-out of renewable energy. However, to decisively sever our dependence on fossil fuels, including Russian gas, a significant scale-up and acceleration in renewable energy production are required.

The role of offshore wind

Offshore wind in the North Sea will play a key role in the decarbonisation of European energy markets and reaching the goals of the Paris Agreement. Offshore wind provides scalable, low carbon energy at a low social cost and with minimal environmental impact, whilst aiding to meet broader security of supply objectives.

Meeting the Paris Agreement will require a major restructuring of the European energy system, including in the countries bordering the North Sea. In this context, offshore wind provides a unique opportunity to significantly increase the capacity of low carbon energy production. The European Commission has estimated that to meet the Paris Agreement an estimated 300GW of offshore wind is required by 2050, of which almost 80% is expected to be deployed in the North Sea.

The North Sea as Europe's green powerhouse

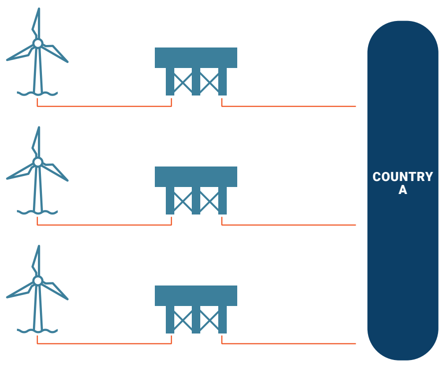
The North Sea provides some of the best conditions for producing green energy from offshore wind, due to its high wind speeds and relatively low water depths. Currently, around 25GW of offshore wind capacity is installed in the North Sea. Therefore, to reach the full potential, there is a need to install ~8-9x the current capacity. To best utilise this resource in a cost-effective manner, a new and radically different approach to the deployment and scaling of offshore wind is required.

In May 2022 the European Commission's President participated in a summit in the Port of Esbjerg, Denmark, alongside the heads of state from Germany, Belgium, Denmark and the Netherlands. In a joint declaration the four countries highlighted the role of the North Sea in securing the EU's energy security and pledged to expand their combined North Sea offshore wind capacity to 65 GW by 2030 and 240 GW by 2050.

The energy island concept

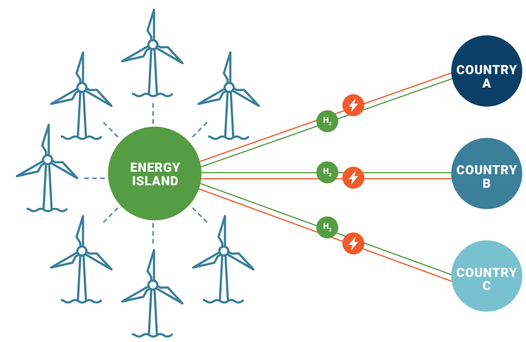
Traditionally, offshore wind has been established in the form of individual wind farms (1 GW capacity) with separate electrical connections to shore. Energy islands constitute a paradigm shift from this approach, allowing for deployment at a much larger scale (10 GW capacity). Also referred to as the "hub-and-spoke" approach, this concept allows for the power output of several wind farms to be bundled together before being sent to shore. In doing so, the energy island concept allows for a more cost-effective deployment of offshore wind by minimising power transmission costs.

TRADITIONAL OFFSHORE WIND



- Offshore wind farms are individually connected to shore
- Potential to export electricity only

ENERGY ISLAND CONCEPT



- Energy island hub connecting several offshore wind parks to multiple countries
- Potential to export electricity and hydrogen

In addition to scalability, the energy island concept allows for better integration of power into the energy system. As the share of renewables increases, the mismatch between energy demand and supply also increases, leading to clean energy production being "lost", as it cannot be utilised in the grid. This issue is known as "curtailment".

CURTAILMENT:
The deliberate reduction in production output below the potential production in order to balance energy supply and demand, when the former exceeds the latter or due to transmission constraints.

One possible solution to the curtailment issue is to use the excess energy production to produce green hydrogen via Power-to-X, which can be used as a fuel in hard-to-abate sectors such as heavy industry and transportation.

Introduction to Copenhagen Infrastructure Partners (CIP)

We are proud to present this year's PCC IMPACT case partner company, a pioneer within renewable energy infrastructure investments, Copenhagen Infrastructure Partners (CIP).

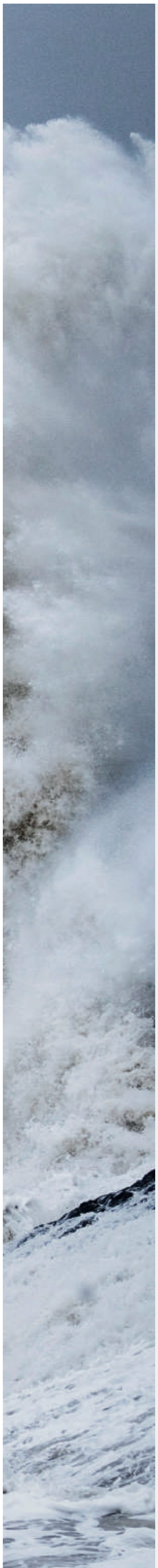
Founded in 2012, Copenhagen Infrastructure Partners today is the world's largest dedicated fund manager within greenfield renewable energy investments and a global leader in offshore wind. The funds managed by CIP focus on investments in offshore and onshore wind, solar PV, biomass and energy-from-waste, transmission and distribution, reserve capacity as well as storage assets and Power-to-X.

CIP manages ten funds and has to date raised approximately EUR 19bn for investments in energy and associated infrastructure from more than 135 international institutional investors. CIP will accelerate its role in the global energy transition and aims to have EUR 100bn under management in green energy investments by 2030.

CIP has been instrumental in driving the development of the Energy Island Concept together with the Danish Government. As a pioneer of the concept, CIP has provided valuable input and analysis to conceptualise the energy island and structure a process to optimise the conditions for both the state as well as the private investor.

CIP has approximately 340 employees and offices in Copenhagen, London, Hamburg, Utrecht, New York, Tokyo, Singapore, Seoul and Melbourne.


“THE PROJECT REPRESENTS
DENMARK’S NEXT STEP
AS A GLOBAL LEADER IN
OFFSHORE WIND...”



CIP is excited to be the Case Company of Polit Case Competition – IMPACT Case 2022. The partnership is an excellent opportunity to gain new perspectives on the North Sea energy island project, and we are eager to see the solutions presented. The project represents Denmark's next step as a global leader in offshore wind - enabling Denmark to reach 100% renewable power supply and become a major exporter of green energy to other EU countries.

The ability to attract the brightest talent is critical to continue the tremendous growth CIP is experiencing. Through your studies, you acquire the analytical skillset and ability to break down and solve complex problems. This is at the core of what we do at CIP - building value that matters through the development of large-scale energy infrastructure projects. Partnering with Polit Case Competition is therefore a great opportunity to showcase why CIP is an attractive workplace and introduce students to a possible career at the firm.

- Thomas Dalsgaard,
Partner at Copenhagen Infrastructure Partners

The Case
– Danish North Sea Energy Island

In June 2020, the Danish Parliament decided to establish the world's first energy islands in Denmark, including one in the North Sea. Shortly after, CIP announced their intention to participate in the projects through a consortium known as "VindØ". The VindØ consortium is composed of two of the largest Danish pension funds, PensionDanmark and PFA, and Denmark's largest utility company Andel.

When fully developed, the energy island in the North Sea is envisaged to have a total capacity of 10 GW– corresponding to roughly 4x the current amount of offshore wind in Denmark. Expected to be established by 2030, the island will mark a decisive step in unlocking the North Sea's role as Europe's future green powerhouse and reaching the EU's target of 300 GW of offshore wind by 2050.

CASE QUESTIONS:
How should CIP design and win the procurement for the Energy Island Project?

(Suggested time allocation %)

This year's case it to help CIP create a plan for the Danish North Sea Energy Island project. As the focus for CIP is to win the procurement and secure an attractive risk-adjusted return for their investors, the solution should have a clear focus on not only profitability, but also how the project fits into the ambitions of the Danish government.

1. Determine the optimal concept solution (Island vs. Platform) for the Energy Island Project based on two scenarios **(50%)**

   a. 10 GW offshore wind energy production, where excess production is not used (i.e. 15% curtailment[1])
   b. 10 GW offshore wind energy production, where excess production is used to produce green hydrogen (1 GW Power-to-X facility) (i.e. no curtailment)

2. Argue how your design fits into the Danish government's climate plan in relation to winning the procurement, under which you must assess the potential carbon reduction **(20%)**

3. Due to the project's scale and character, CIP must be aware of risks. Identify various risks and possible mitigation measures related to the project in regards to both the construction and operations **(30%)**

Rules

You will be judged on the entire aspect of your analysis and solution, including the decisions you make along the way, and how you document and argue for them.

The slide deck for your final presentation should be submitted as a single PDF file in 16:9 format through innoflow no later than 18.30. The maximum number of pages is 10. The oral presentation should last no longer than 10 minutes.

[1] See page 2 for the definition of curtailment.

Background Material

Offshore Wind
What is offshore wind?

Wind turbines generate power as the wind force makes the blades turn. An array of gears connected to the rotor will transmit the speed to a generator, transforming kinetic energy into electricity. Afterwards the electricity is transmitted by cables to an offshore station.

Why offshore wind?

There are several conditions which favour offshore wind compared to onshore wind.

- Turbines can generate significantly more power from even small gains in speed. As wind speeds tend to be higher at sea, an offshore turbine will tend to produce more electricity than its onshore counterpart.
- While wind power is highly intermittent, the wind is steadier at sea resulting in a more stable supply of energy.
- Very few offshore space constraints and a reduction in population proximity issues related to noise and landscape views allow for larger wind turbines and wind farms.

Electricity price

A Power Purchase Agreement (PPA) is a contract between two parties, one which generates power and one which purchases the power. For energy developers like CIP, PPAs reduce price risk by ensuring offtake at a stable price. To hedge electricity price risk, assume CIP enters a PPA at a fixed real price of 50.3 EUR/MWh.

CALCULATING ANNUAL ENERGY PRODUCTION

The annual energy production is determined by the installed capacity and expected full load hours.The energy production can therefore be calculated as:
annual energy production = installed capacity x avg. annual full load hours

Offshore wind cost and construction

Due to continuous technological innovation, the cost of utilizing offshore wind energy has decreased and is expected to decrease further in the upcoming years.

Costs related to the construction of the wind farms make up most of the wind turbine's lifetime cost base, whereas running operating costs make up a lesser share.

PARAMETERS	OFFSHORE WIND
CAPEX (MEUR/MW)	2.80
OPEX (MEUR/MW/YEAR)	0.039
LIFETIME (YEARS)	30
CONSTRUCTION TIME (YEARS)	2
CURTAILMENT (%)	15
AVG. ANNUAL FULL-LOAD HOURS	4,800

WATT (W) is a measure of production capacity, while watt hours (Wh) measures power production per hour. A 1 megawatt (MW) wind turbine can produce 1 MWh per hour (assuming full load). 1 gigawatt (GW) corresponds to 1000 MW.

LOAD FACTOR is the ratio between the actual power generation over a period relative to the maximum power generation.

CARBON REDUCTION FACTOR is the reduction in CO_2 emission per unit of energy production.

	OFFSHORE WIND	POWER-TO-X
TECHNOLOGICAL MATURITY	High	High - at small scale
LARGEST OPERATIONAL FACILITY	1.32 GW - Hornsea 2 (UK)	10 MW - Refhyne (GER)
LARGEST FACILITY UNDER CONSTRUCTION	3.6 GW - Doggerbank (UK) Expected operational 2026	200 MW - Rotterdam (NED) Expected operational 2025

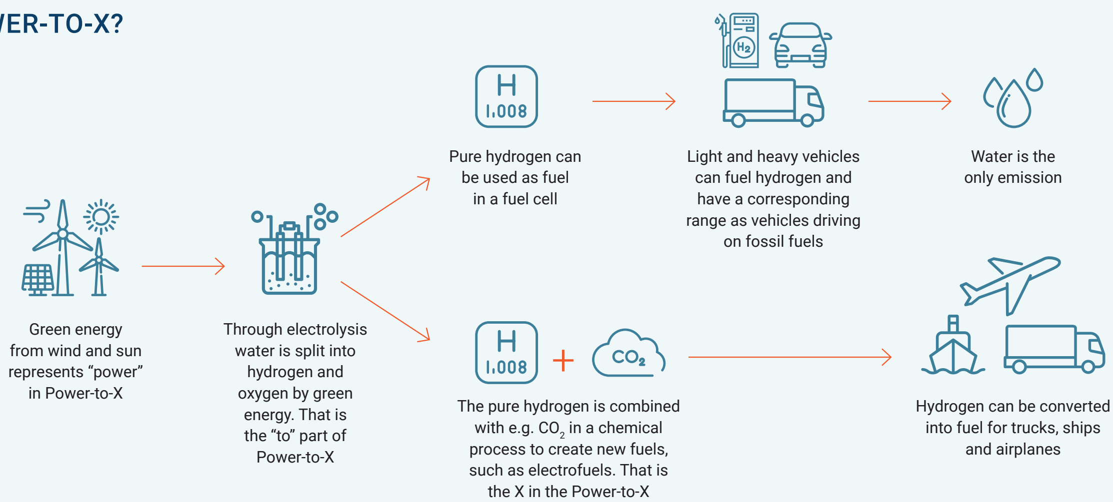
Power-to

What is Power-to-X?

Power-to-X is the process of utilizing electricity from renewable energy sources (e.g. wind turbines) to produce hydrogen, which can be converted into other useful products such as methanol and ammonia (electrofuels). Power-to-X products can be used to replace fossil fuels in various applications, such as heating, transportation, and industrial processes.

X

POWER-TO-X?



Source: Brintbranchen, https://brintbranchen.dk/om-brint/

Why Power-to-X?

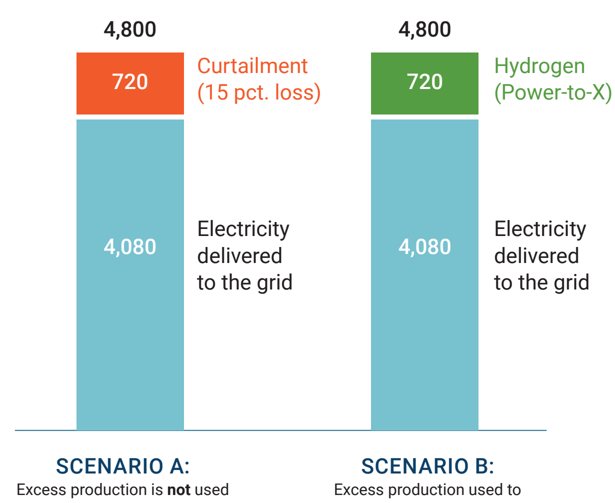
Power-to-X is considered a key component in achieving a carbon-neutral society, as it allows for the replacement of fossil fuels in hard-to-abate sectors where direct electrification is challenging due to storage and/or transportation problems.

Power-to-X as a flexibility provider

The future energy system needs the flexibility to counteract potential curtailment issues, e.g. when energy supply exceeds demand. In addition to interconnectors, Power-to-X facilities significantly increase the ability to utilize excess supply as energy curtailment can be redistributed to produce green hydrogen. The green hydrogen can then be sold and used as an alternative to direct electrification in hard-to-abate sectors.

ILLUSTRATION OF CURTAILMENT FOR 1GW OFFSHORE WIND

(4,800 AVG. ANNUAL FULL-LOAD HOURS)

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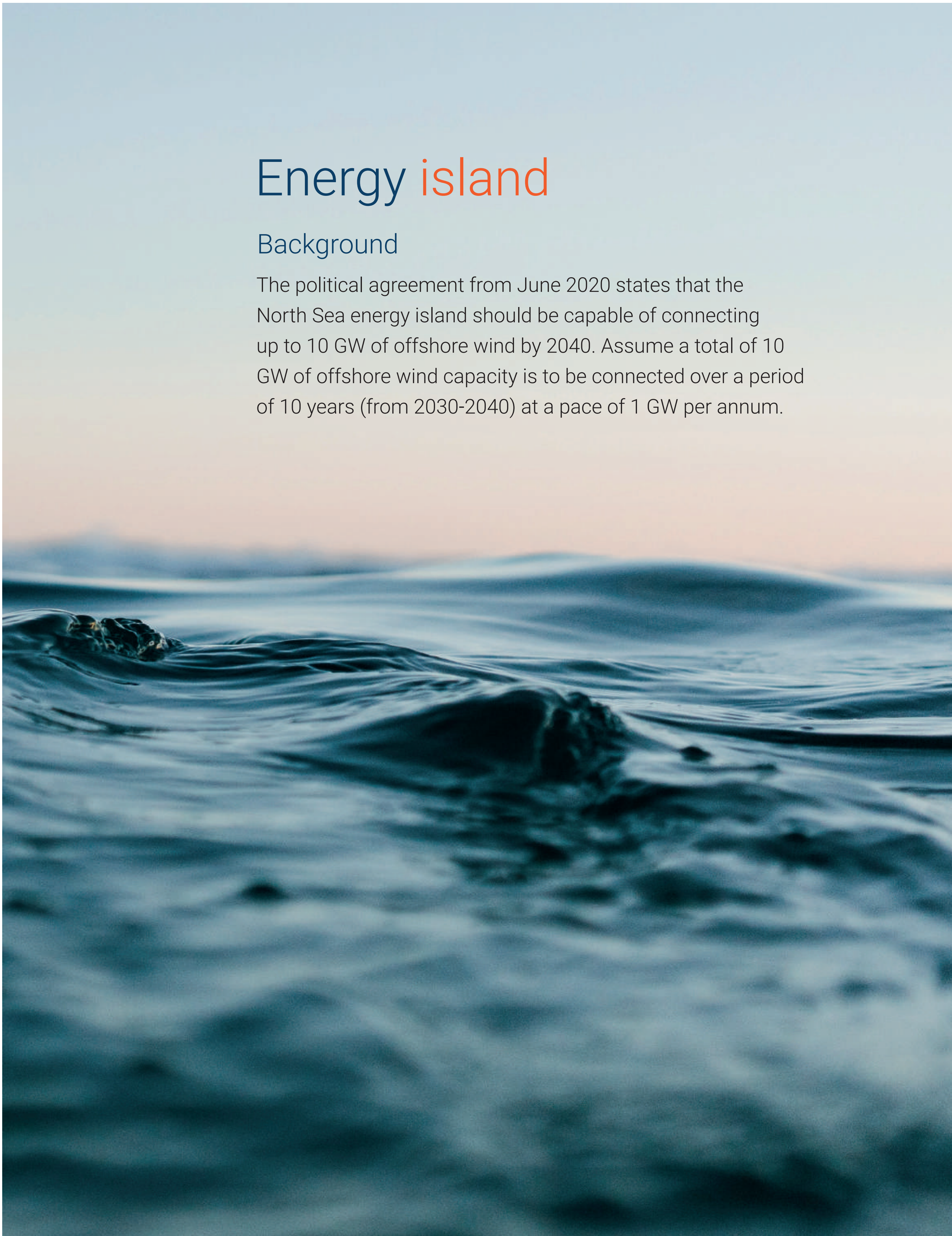
Price of hydrogen

To hedge hydrogen price risk, assume CIP enters a PPA locking in at the current real market price of 70.6 EUR/MWh.

Technology and construction of Power-to-X

The Power-to-X plants will be using electrolysis to produce hydrogen. Electrolysis is an old and well-known technology. However, no plant on a commercial scale, larger than 100 MW, currently operates. The technological development is rapid and multiple commercial scale plants are under construction and will be commissioned in the upcoming years. But considerable uncertainty is still related to the technological advancements and feasibility on this scale.

PARAMETERS	POWER-TO-X
CAPEX (MEUR/MW)	0.450
OPEX (% CAPEX, P.A.)	5
LIFETIME (YEARS)	30
CONSTRUCTION TIME (YEARS)	3
CONVERSION EFFICIENCY (%)	70
AVG. ANNUAL FULL-LOAD HOURS	Equal to offshore wind curtailment (15%)



Energy island

Background

The political agreement from June 2020 states that the North Sea energy island should be capable of connecting up to 10 GW of offshore wind by 2040. Assume a total of 10 GW of offshore wind capacity is to be connected over a period of 10 years (from 2030-2040) at a pace of 1 GW per annum.

Artificial Island

(Concept A)

Definition: An artificial structure made either of sand, rock, concrete blocks (caissons) or a combination of these.

Picture: Illustration of artificial rock-based energy island (courtesy of VindØ consortium)

- **Full-scale (10GW) upfront:** An artificial island can comprise a larger structure enabling the connection of up to 10GW of offshore wind.
- **Non-modular:** The artificial island cannot be easily expanded, i.e. it is limited by its initial construction size.
- **Flexibility (vacancy risk):** As the build-out of offshore wind occurs incrementally over 10 years, the artificial island will be "oversized" (i.e. not fully utilised) from its inception until the final offshore wind farm is connected. The cost of oversizing the island is referred to as vacancy cost / idle-asset cost.
- **Economies of scale:** Constructing a full-scale artificial island from the onset enables significant economies of scale, as the marginal cost is low.
- **Innovation:** An artificial island provides ample room for hosting innovative technologies, such as Power-to-X (hydrogen production) without the need for expansion.

Platform

(Concept B)

Definition: A steel substructure (jacket) and topside designed to house electrical transmission infrastructure.

Picture: Dolwin3 (CIP project)

- **Fixed-unit scale (1GW):** A platform solution only enables the connection of 1 GW of offshore wind per platform. In other words, whereas one artificial island can host 10 GW, 10 platforms are required to host 10 GW.
- **Modular:** Unlike the artificial island, the platform solution is highly modular as it can be easily expanded (by constructing additional platforms).
- **Flexibility (vacancy risk):** The platform concept provides greater flexibility, as its modular nature enables the build-out of transmission via platforms to better follow the pace of offshore wind, thereby minimising vacancy (or “idle-asset”) costs.
- **Innovation:** The platform concept can only accommodate a maximum of 0.5 GW per platform (i.e. two platforms needed for 1 GW Power-to-X/hydrogen production) due to load-bearing capacity restraints. Note: a platform cannot contain both transmission equipment and Power-to-X (e.g. 5 GW transmission and 0.5 GW Power-to-X capacity would require a total of 6 rather than 5 platforms).

SUMMARY OF COMPARISON OF THE TWO SOLUTIONS

	A) Artificial Island	B) Platform (Jacket)
SCALE	10 GW	1 GW
MODULARITY	None	High
ECONOMIES OF SCALE	High	None
POTENTIAL FOR INNOVATION (WRT. POWER-TO-X)	High	Low

The technology for electrolysis facilities approaches a level ready for large-scale commercial use. Although the current technology for Power-to-X experiences a conversion loss when producing green hydrogen, the conversion efficiency is close to 70% meaning that 1 GWh of electricity can produce 0.7 GWh of green hydrogen.

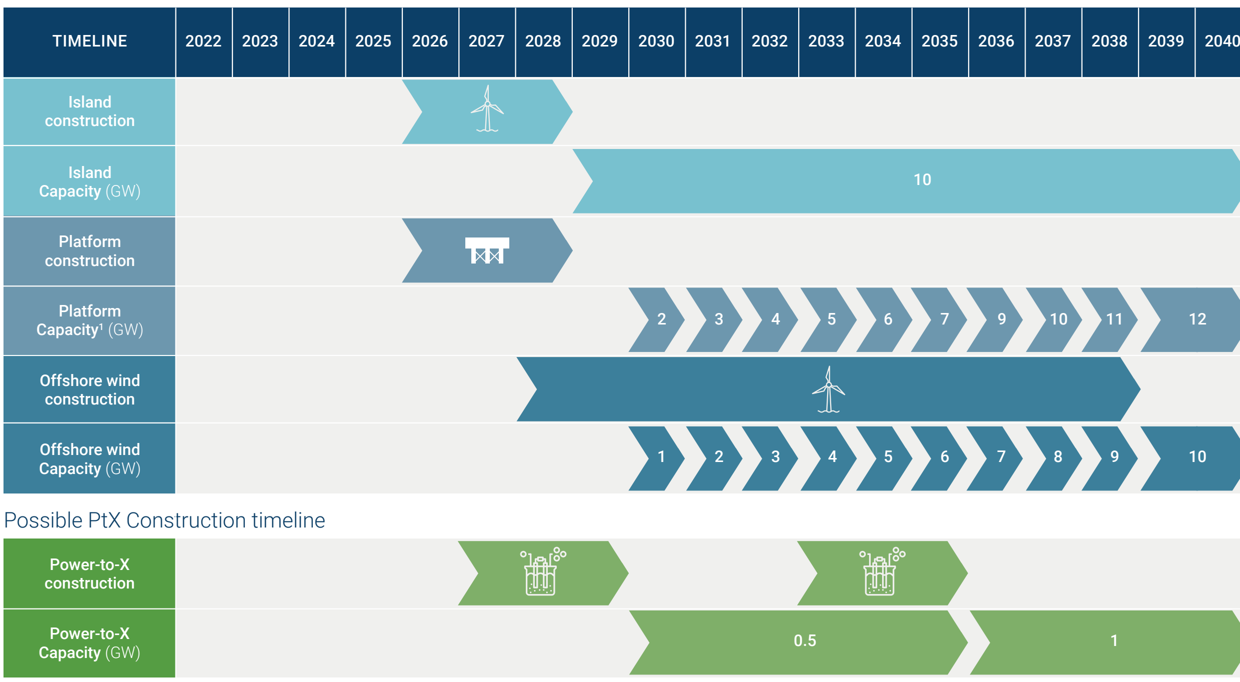
Decommissioning costs

Once the assets reach their expected lifetime, all facilities are scrapped. It is assumed that the cost of scraping the facilities equals the value of the scrapped materials (i.e. no decommissioning costs).

PARAMETERS	ARTIFICIAL ISLAND (UNIT: 10 GW)	PER PLATFORM (UNIT: 1 GW)
CAPEX (MEUR)	1,500	270
OPEX (% CAPEX, P.A.)	1	2
LIFETIME (YEARS)	70	35
CONSTRUCTION TIME (YEARS)	4	4
POWER-TO-X CAPACITY	10 GW	0.5 GW (per platform)
CO_2 EMISSION	840,000 tons	45,000 tons (per platform)

Suggested timeline of the construction phase of the project

CIP has suggested this timeline, depending on your preferred solution



Notes: (1) Platform capacity covers either 1 GW electricity platform or a 0.5 GW PtX platform

Levelized Cost of Energy

The levelized cost of electricity (LCOE), or levelized cost of energy, is a measure of the average net present cost of electricity generation for a generator over its lifetime. It is used to compare the competitiveness of different methods of electricity generation.

LCOE is calculated as the ratio between all the discounted costs over the lifetime of an electricity generating plant divided by the discounted sum of the actual energy amounts produced. The discount rate applied should reflect all the risks associated with the investment.

$$\mathbf{LCOE} = \frac{PV\ (\text{costs over lifetime})}{PV\ (\text{electrical energy produced over lifetime})} = \frac{\sum_{t=1}^{n} \frac{I_t + M_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}}$$

- I: **Investment** (CAPEX)
- M: **OPEX**
- E: **Energy Production**
- r: **Discount rate**

The applicable discount rate
for both energy island concepts is 6-8 %

Climate

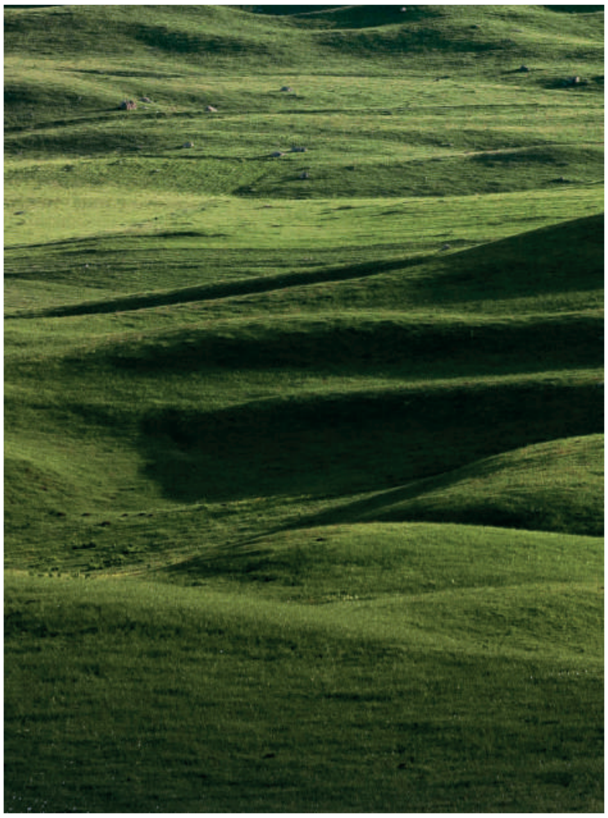
The climate is changing and there is a worldwide focus on how to limit global warming to 1.5 degrees Celsius in accordance with the UN Paris agreement. To achieve this temperature goal, we need to reduce our greenhouse gas emissions as soon as possible.

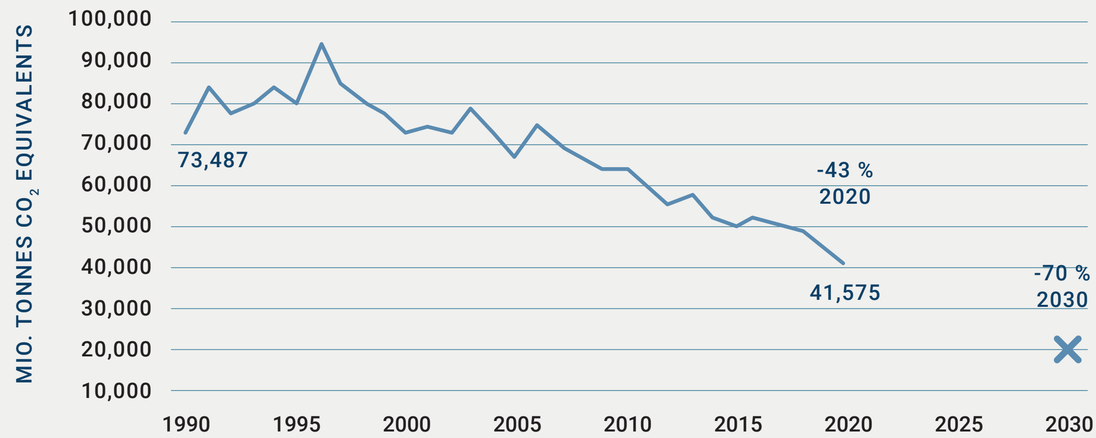
A tool invented to try and mitigate the emission of greenhouse gasses is carbon credits. The carbon market constructs a ceiling on the amount of carbon dioxide emitted, thereby limiting the pollution. The idea is to make market mechanisms regulate the emissions between industries and market agents by allowing free trade of these carbon credits. It simultaneously creates an incentive to work with less carbon intensive approaches by creating a cost to emission.

A **carbon credit** is a generic term for any tradable certificate or permits representing the right to emit a set amount of carbon dioxide or the equivalent amount of a different greenhouse gas.

Denmark as a green pioneer

Denmark has the ambition to be a pioneer within the green transition and set an example or other countries on how to reduce greenhouse gas emissions with innovative low-carbon solutions and an ambitious agenda. The Danish government published in 2021 a new climate law stating how to achieve a greener and more sustainable future. With the latest climate law, it has been decided to reduce the overall Danish carbon emission by 70 % by 2030 and have a net-zero emission by 2050. In 2020 Denmark emitted 42 million tonnes of CO_2-equivalents, corresponding to 7.1 tonnes of CO_2-equivalents per Danish citizen.





Note: Pollution is exclusive CO_2 from biomass and international transportation
Source: DST DRIVHUS

Many of the government's analyses indicate the reduction potential to drastically decline over time, because many technologies, needed to reach the goal, require significant capital investments, and take time to implement. For that reason, the government stresses the importance of a fast-decision-making process, and they have set a deadline in 2025, when all decisions needed to reduce the carbon emission by 70 % by 2030 have been made.

Danish energy sector

The Danish energy sector makes up an important part of the government's green transmission plans. The sector has already been through significant changes on its way to a more sustainable future, as wind, solar and biomass energy systems largely have replaced coal and oil, while energy optimizations have been made also. However, sustainable energy is still a central part of the government's plans, as it is a central part of the transmission of the other sectors. A successful climate transmission is thus conditional on successful electrification of the energy sector.

Wind energy and Power-to-X are expected to play an essential role in the energy transition and can contribute to significant carbon reductions. With Power-to-X, excess energy production, which would otherwise be curtailed, can be utilised to produce green hydrogen.

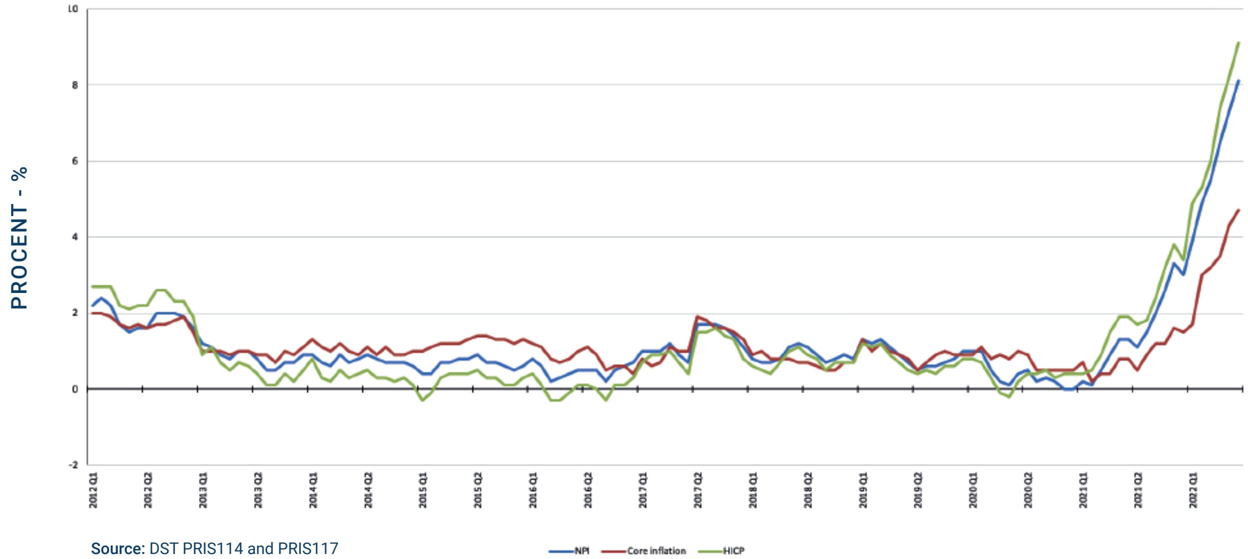
Carbon reduction factor	Offshore wind	150 tonnes CO_2 / GWh

Is the global economy experiencing a macroeconomic regime shift?

Inflation

The economy has had a long period with economic growth for both households and companies. This is among many things due to historically low inflation and interest rate levels that have created attractive investment opportunities. However, this picture has been put under pressure in 2022, where high inflation have dominated the economic agenda in many countries. The trend is clear in all western economies, and in Denmark the inflation was 8.2 % in June 2022, the highest level observed since 1983, where the number was 8.7 %. Hence, the low inflation regime with low interest rates and attractive financing terms is experiencing an uncertain future, which has already set its mark on the stock market and central banks have increased the interest rates for the first time in many years and have announced more to come.

Figure: Inflation development, 2012 - 2022



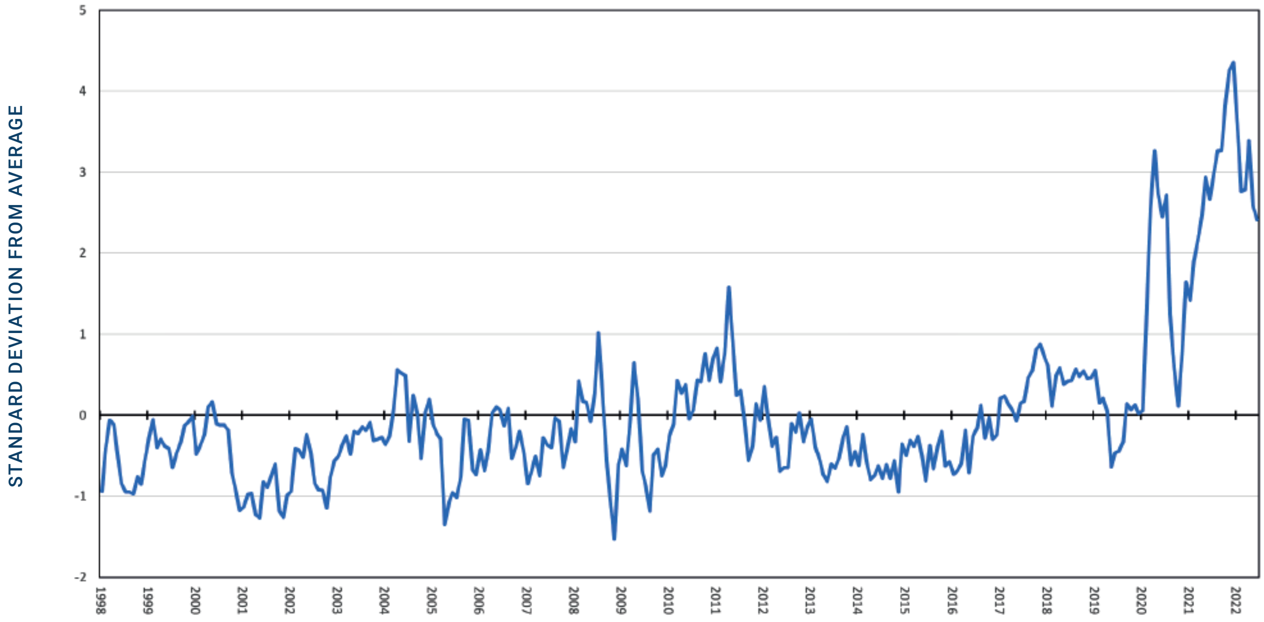
Source: DST PRIS114 and PRIS117

Supply chain issues

The economy has since the outburst of the Covid-19 experienced an imbalance in the economy, where alternately over time supply has not met demand and vice versa. That has created a worldwide supply-chain crisis affecting all industries and sectors. Due to the complexity of the economy, it is hard to give one exact reason for the outcome. It is more likely due to a perfect storm caused by a mixture of lockdowns, geopolitical conflicts, expansionary fiscal and monetary policy, single events such as the ship Ever Given's blockade of the Suez-canal, general economic instability, etc. These factors have created labour shortages, lack of equipment availability and global bottlenecks.

The supply-chain crisis has at first resulted in an increase in the energy prices also caused by the conflict in Ukraine, because Russia is a big gas supplier. It has a strong impact on other products and services, where energy is used in production. For that reason, increased energy prices have created an economic environment in which comprehensive inflation increases can occur across all sectors. The crisis has also created a general shortage of resources going into different production and construction processes, potentially delaying, or even preventing projects from being realized in the near future.

Figure: Global supply chain pressure index



Source: Federal Reserve Bank of New York

Economic projections

Amid considerable uncertainty, IMF's World Economic Outlook from April 2022 projects global growth to slow from an estimated 6.1% in 2021 to 3.6% in 2022 and 2023. This is respectively 0.8 and 0.2 percentage points lower than projected in January. Some professional analysts even believe we are on the verge of a recession, as they point to the supply issues, inflation crisis and armed conflict in Ukraine. The risk of a recession is thus closely linked to the development of inflation, supply issues, and geopolitics. A longer-lasting high inflation regime will likely increase unemployment and decrease economic activity. It will mainly be due to a high-interest rate environment in combination with an increased risk premium, making the financing terms less attractive and thus slowing down investments. The majority of projections expect most supply issues will begin to resolve in 2023 amid significant uncertainty.

7

Rules and regulation

1. In Polit Case Competition IMPACT 2022, you are judged solely by the panels of semi-finale and finale judges, based on your oral presentation, your supporting slide deck, and the subsequent Q&A session. You will be judged on the entire aspect of your analysis and solution, including the decisions you make along the way, and how you document and argue for them.

2. You must submit your slide deck as a single pdf file in 16:9 format through pcc.innoflow.io no later than 18.30. Late submissions will not be considered.

3. Your presentation slide deck must not contain more than 10 slides, including the frontpage. Any supporting documents are not required, nor considered.

4. All content presented must be the original work of the group. In addition to the case information and expert interviews, all publicly available information may be used. Between 10 am and 18.30 pm, no outside aid is permitted, nor is communication with other teams.

5. The oral presentation must not last longer than 10 minutes.

6. In case of organizational questions, these should be addressed to a member of the Polit Case Competition staff in person or by e-mail to info@politcasecompetition.com. We cannot provide input to the case contents.

7. The case must be solved on the premises provided as part of Polit Case Competition 2022.

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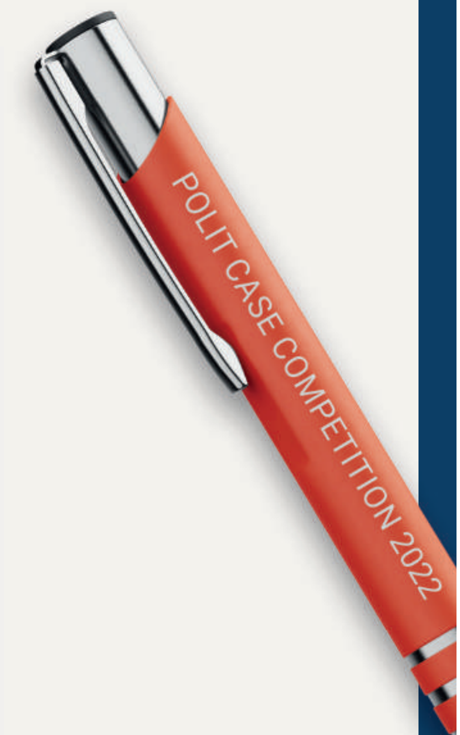

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Good luck

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