ENERGY ISLANDS

DANISH ENERGY ISLANDS AND THE REALIZATION
OF THE NORTH SEA'S ENERGY POTENTIAL

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BACKGROUND FOR THE ANALYSIS AND SUMMARY OF RESULTS

BACKGROUND

- As part of the Danish climate agreement for energy and industry in June 2020, it was decided to build the world's first two Energy Islands in Denmark, which marked a groundbreaking step in the green transition.
- The Energy Islands are considered visionary projects that can speed up and realize an unprecedented expansion of offshore wind turbines.
- Belgium has like Denmark seen the potential of Energy Islands, and in February 2023 the task of establishing Belgium's Energy Island was awarded, to start in 2024.
- Since then, the tender for the Danish Energy Island in the North Sea has been postponed indefinitely.
- The question remains, what can we learn from Belgium? And what is it that challenges the economy in Danish Energy Islands?
- These questions are addressed in this concept analysis - and in particular it is highlighted what we believe is conceptually to be gained if Energy Islands are thought of as **integrated energy systems**, with a focus on system optimization and transport of energy such as hydrogen , rather than as production hubs for electricity.

RESULTS

- The world's first Energy Island, Princess Elisabeth Island in Belgium, has two purposes; partly to collect the energy from 3.5 GW Belgian offshore wind in one powerful onshore connection. And partly, to connect Belgium with the electricity grid in the UK and Denmark.
- This makes sense because Belgium needs to decarbonise the country's energy production by increasing the share of renewable energy in the country's energy mix.
- Denmark has a high share of renewable energy in the energy mix, and with full expansion of the announced ambitions for offshore wind, will have an energy production that far exceeds our electricity consumption. This is also the reason why we are discussing power-to-x and the export of hydrogen.
- Calculations conducted by COWI and Brinckmann show that production of hydrogen closer to offshore wind turbines, out on an Energy Island, entails considerable commercial advantages - which also contribute to lower the cost side.
- The same effect has the scale - and integration of several Energy Islands - as one **integrated energy system**, from which the energy is **transported as hydrogen**, rather than as electricity.
- The results are in line with similar studies from Energinet and DTU.

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INTERESTING OBSERVATIONS

With the announced ambitions for offshore wind and with Denmark's already high share of renewable energy in the energy mix, Denmark's future energy production will far exceed the Danish electricity consumption. Therefore, it makes sense to talk about power-to-x and the export of hydrogen. In that context, the most valuable competitive parameter is the Levelized Cost of Hydrogen (LCoH).

1 In comparison with a system-integrated Energy Island, the government's model for an Energy Island will result in **16% higher production costs** for hydrogen (LCoH).

- The increase in LCoH is driven by the requirement of electrical infrastructure.

2 The government's model for an Energy Island includes CAPEX of **DKK 20-30 billions higher** than a system-integrated Energy Island.

- The cost increases are driven by electrical infrastructure (HVDC, ON/OFF converters).

3 The transmission loss in the HVDC cable drives a **3,7%** lower hydrogen production in the government's model compared to a system-integrated Energy Island.

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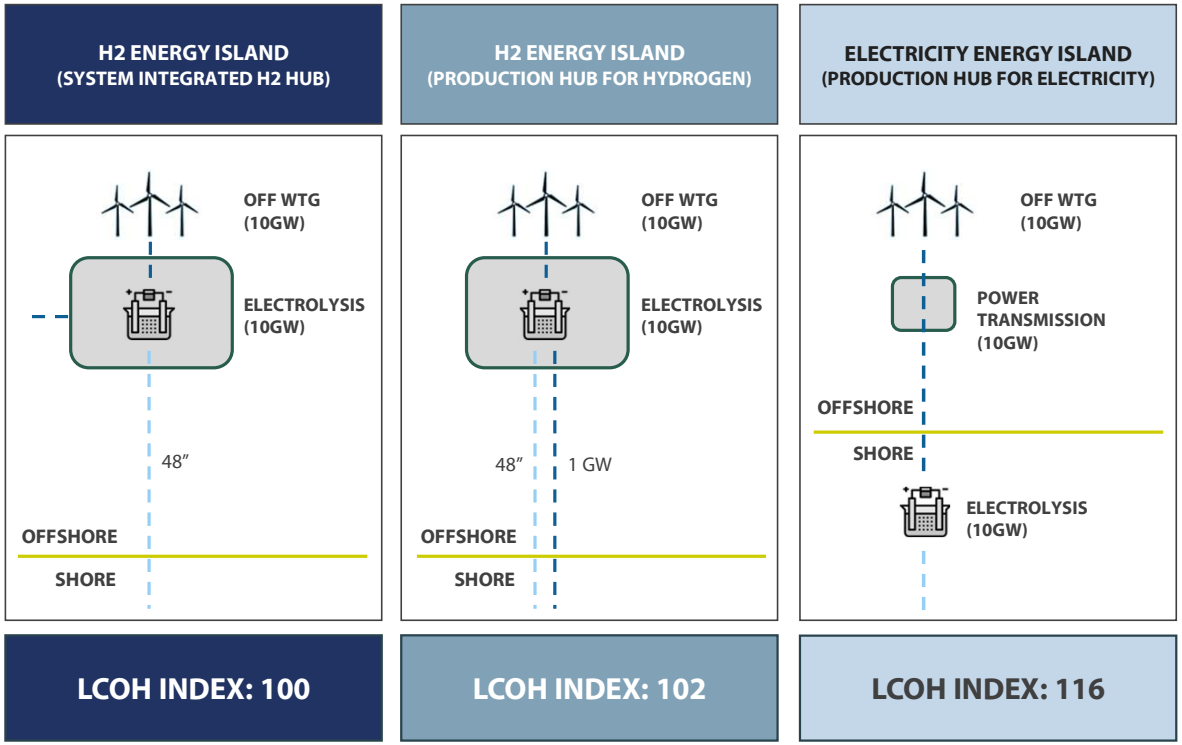
COMPARISON ACROSS ENERGY ISLAND CONCEPTS

Scenario overview and modelling basis



Assumptions

To assess the advantages for hydrogen production on Energy Islands a comparison is made between:

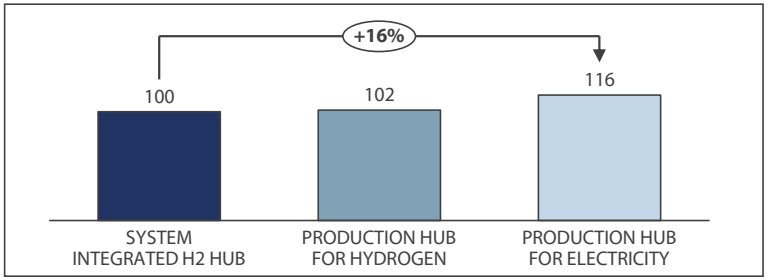
a) Onshore hydrogen production (electrolyser) sourced by an Energy Island (via a behind-the-meter connection, i.e. no system fee's).

b) Hydrogen production on an Energy Island with transport of hydrogen to shore via pipeline with a grid connection to shore.

c) Hydrogen production on an Energy Island with transport to shore via pipeline without a grid connection to shore.

NB: The focus is solely on effects regarding wind turbines, electrolysis and system effects.

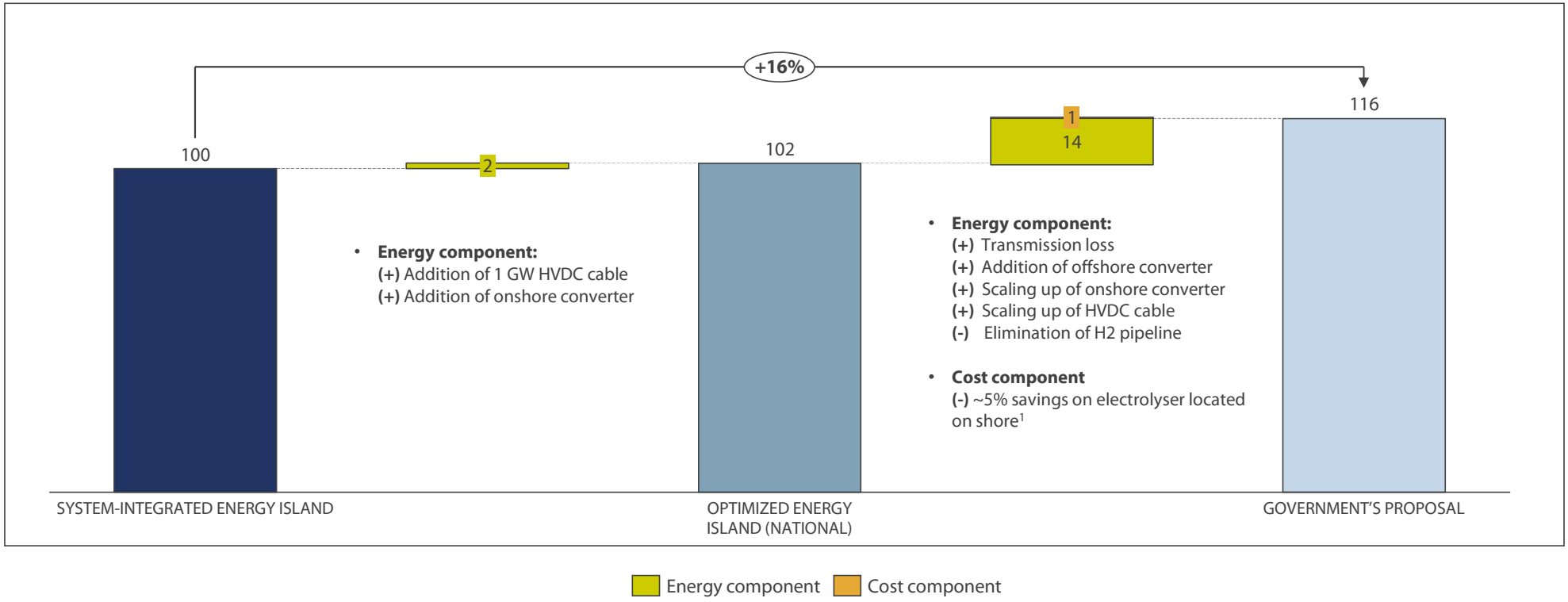
LCoH* results



*) Levelized cost of hydrogen

ELECTRICAL INFRASTRUCTURE INCREASED LCOH BY 16%

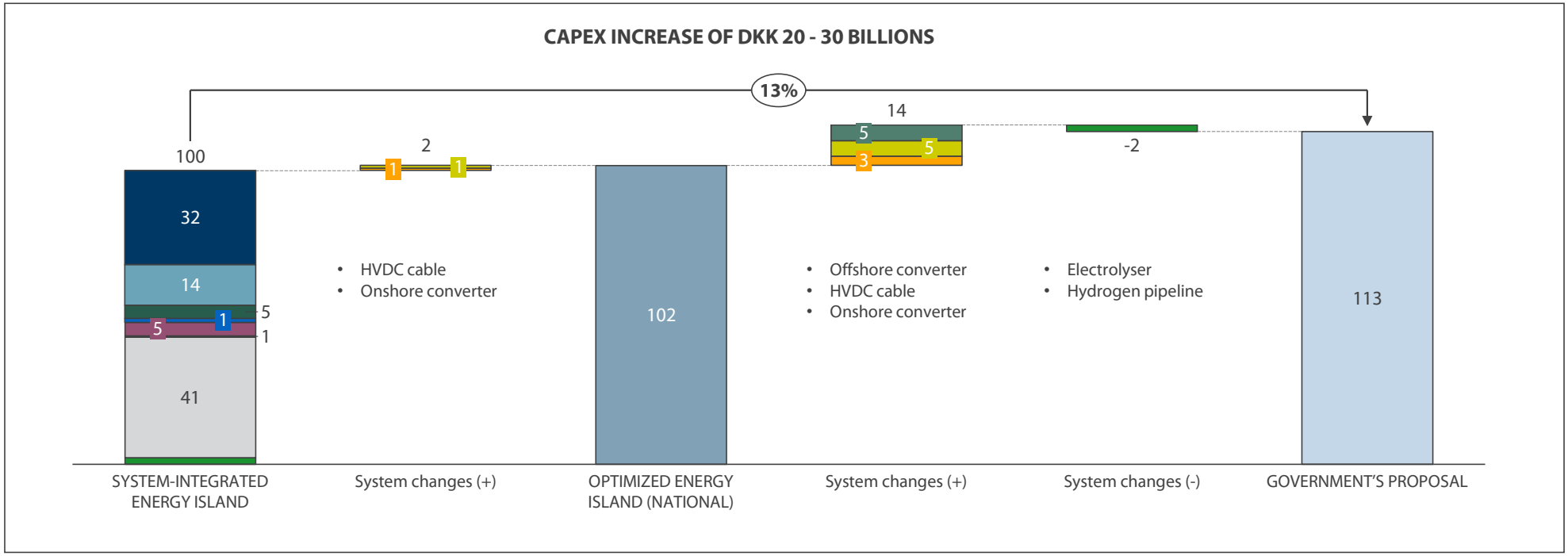
LCoH comparison - System LCoH development (%)



1) DNV-GL: Screening of possible hub concepts to integrate offshore wind capacity in the North Sea

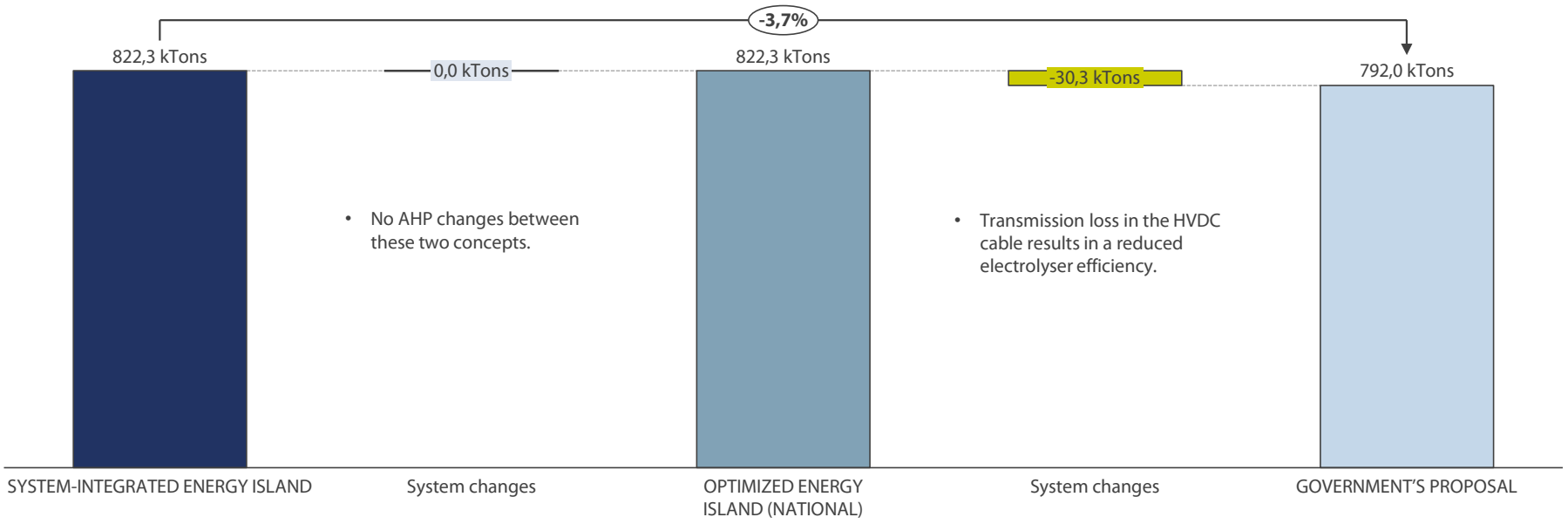
ELECTRICAL HVDC INFRASTRUCTURE DRIVES SIGNIFICANT COST INCREASES IN CAPEX

CAPEX development across concepts (%)



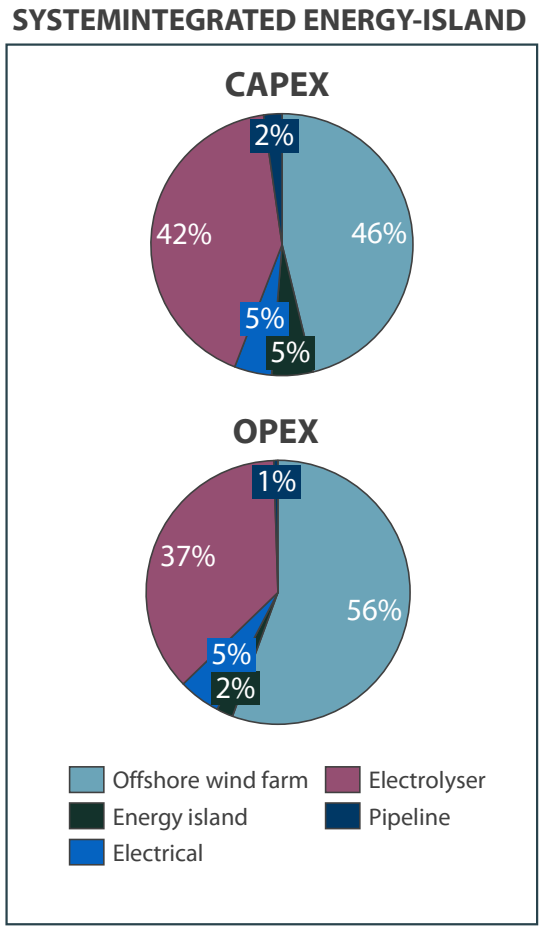
3,7% REDUCTION IN HYDROGEN PRODUCTION BY ESTABLISHING HVDC CABLE

Annual Hydrogen Production comparison



Additional considerations

- In this analysis, a relation of 1:1 between OWF and electrolyser has been assumed. Overplanting would increase full load operational hours and decrease LCoH further for hydrogen production offshore on the energy island.
- Offshore hydrogen production solves the problem of limited grid capacity and constraints of the transmission grid.
- In this analysis, and for the scenario in which energy is only transported as electricity in electrical transmission cables, it is assumed that the grid connection point onshore is only at one location. Distributing the electricity to other locations and/or to other countries will increase the CAPEX even further for this scenario.
- Germany has defined themselves as a hydrogen import country and there is a very strong demand and export case for DK export of green hydrogen to Germany.



Sources: Energinet: Systemperspektivanalyse 2022, DTU: Onshore, offshore or in-turbine electrolysis?, DNV-GL: Screening of possible hub concepts to integrate offshore wind capacity in the North Sea , In-house data (COWI & Brinckmann)

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