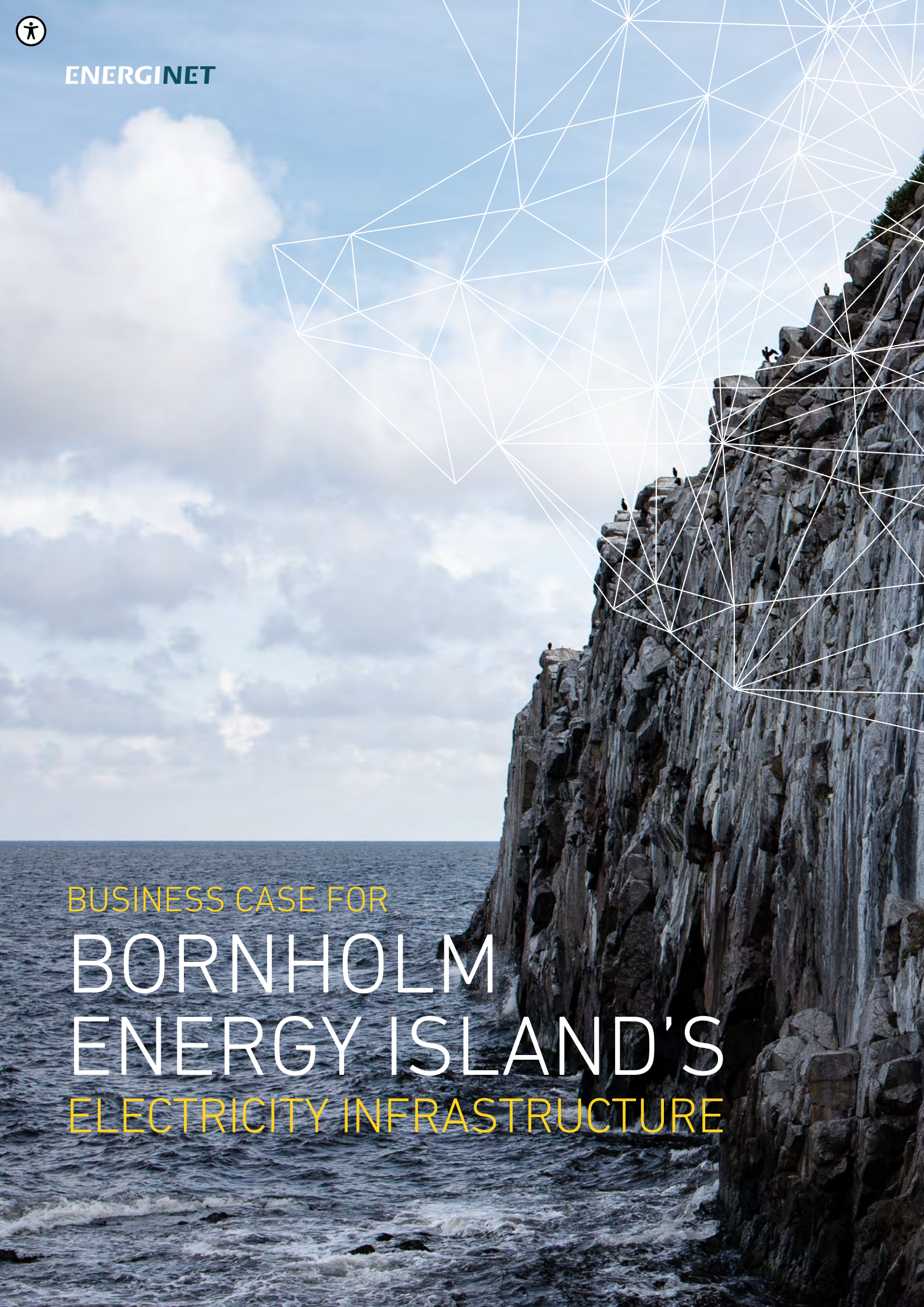
ENERGINET



BUSINESS CASE FOR

BORNHOLM ENERGY ISLAND'S ELECTRICITY INFRASTRUCTURE

Business case for Bornholm Energy Island's electricity infrastructure

Approved by Energinet's supervisory board: 29 March 2022.

Energinet's purpose under the Danish Act on Energinet:

Energinet's purpose is to own, operate and expand general energy infrastructure, perform related tasks and thereby contribute to developing a climate-neutral energy supply.

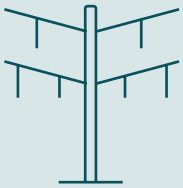
Energinet must consider security of supply, climate and the environment, and ensure open and equal access for all users of the grids and efficiency in their operation.

CONTENTS

BUSINESS CASE FOR BORNHOLM ENERGY ISLAND'S ELECTRICITY INFRASTRUCTURE

ECONOMICS OF BORNHOLM ENERGY ISLAND'S ELECTRICITY INFRASTRUCTURE – AT A GLANCE

In this business case, Energinet assesses the economic value of the Bornholm Energy Island's electricity infrastructure by analysing two alternatives: interconnections to both Denmark and Germany, compared to an interconnection to Denmark only.

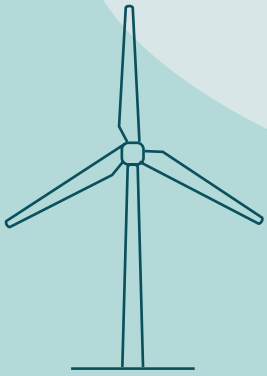


DKK 17 BILLION

Construction costs for the elements of the Bornholm Energy Island's electricity infrastructure which Energinet will build, own and operate.

DKK 20 BILLION*

Connecting the Bornholm Energy Island to both Denmark and Germany achieves a 9-figure net benefit compared to if it is only connected to Denmark.



*There is considerable uncertainty about the specific economic benefit. This uncertainty is due in part to the assumptions in alternative 2, whereby large volumes of wind power are supplied to Eastern Denmark, but demand does not increase in step.

40,000 TONNES IN DENMARK

Reduction in carbon emissions in Denmark in 2040 as a result of the Bornholm Energy Island (connected to both Denmark and Germany).

3,100,000 TONNES IN EU

Reduction in carbon emissions in Europe in 2040 as a result of the Bornholm Energy Island (connected to both Denmark and Germany).

SIGNIFICANT RISKS

Bornholm Energy Island is to become world's first energy island. The innovation bar has been set high, and the decisions bound by the climate agenda add an external time pressure for the project. Establishment of the Bornholm Energy Island's electricity infrastructure is therefore a project that carries high risk. Three key sources of project risk are listed below:

- **Ambitious time schedule:** Risk of delays if business partners, environmental assessment processes, regulatory approvals, suppliers and supply chains are unable to meet the assumed time schedule.
- **New technology:** Standards for connecting HVDC plant have not yet been developed. There is thus a risk of prices and delivery times for Energinet's plant increasing.
- **Uncertain assumptions:** High uncertainty about future market conditions, particularly in light of the war in Ukraine, ongoing negotiations on shared ownership of the connection to Germany, and the possibility of insuring offshore construction work are examples of uncertain assumptions which could potentially have a major impact on project economics.

WHAT FACTORS COULD AFFECT THE RESULTS OF THE ANALYSIS?

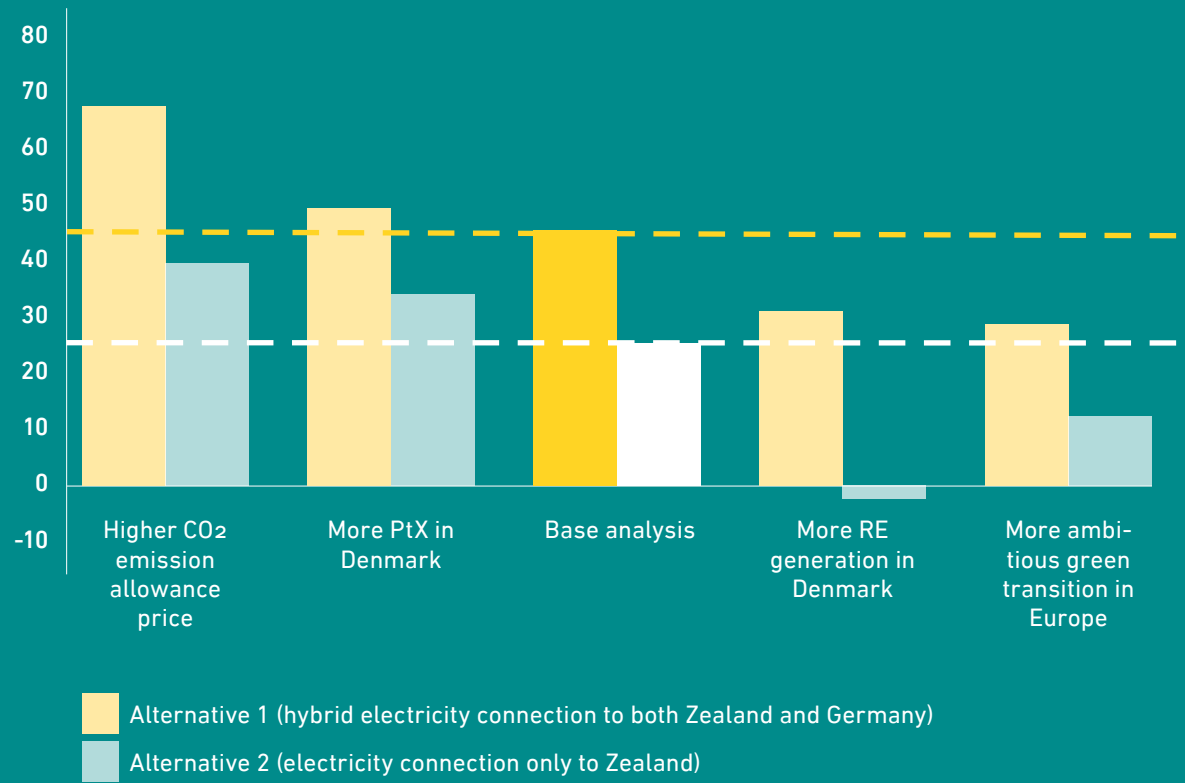
Future development of the energy system could take several paths. These are some of the key elements that could affect the business case for the Bornholm Energy Island's electricity infrastructure:

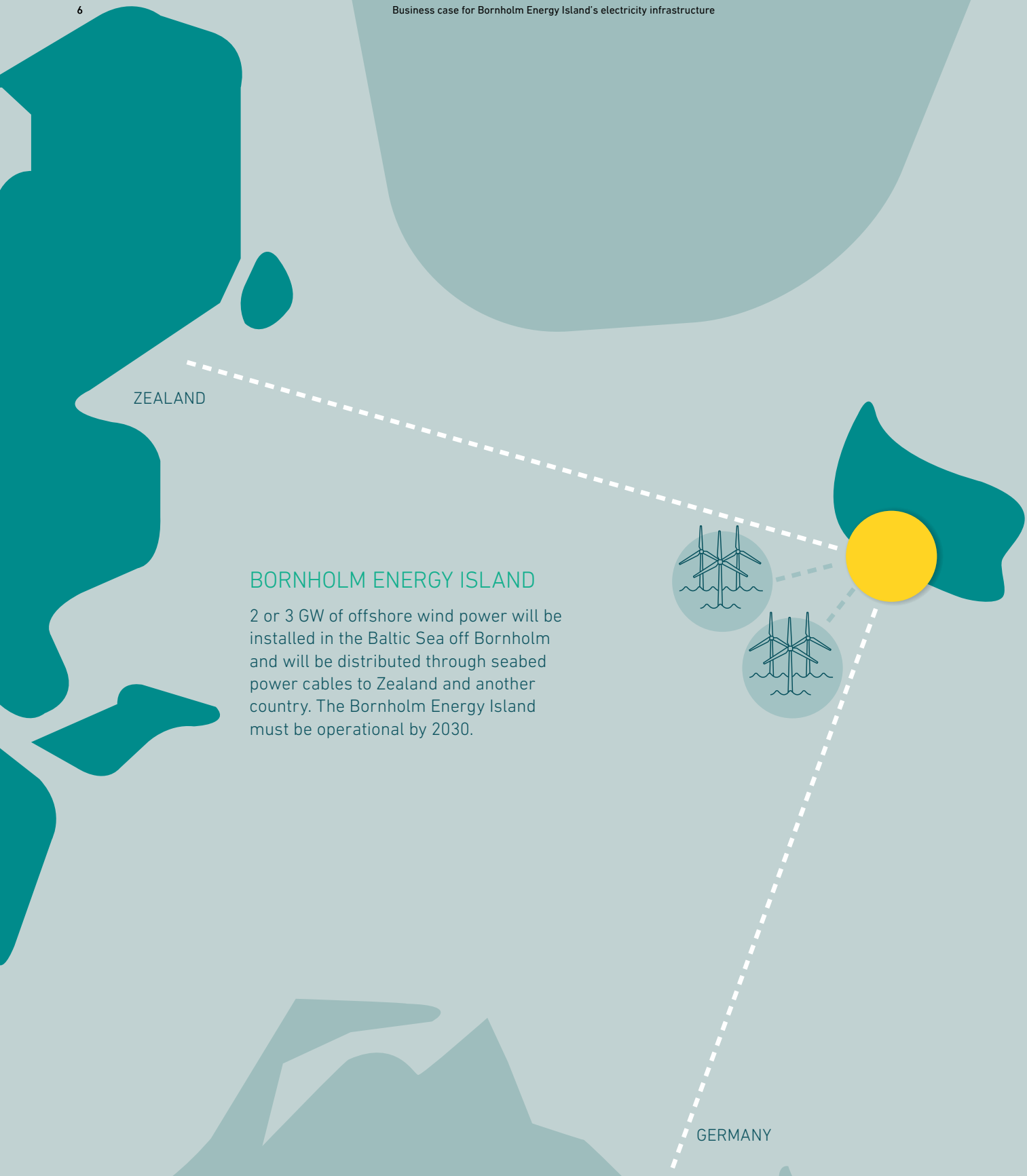
1. Carbon emission allowance prices are higher than assumed
2. Electricity consumption in Denmark for hydrogen production via Power-to-X is larger than assumed
3. Renewable energy generation in Denmark is higher than assumed
4. The green transition for energy in Europe becomes more ambitious than assumed.

For the developments analysed, the analyses show that it is better for Denmark and Europe for the Bornholm Energy Island to be established with a connection to Germany, as opposed to a pure connection from Bornholm to Zealand.

But the difference in the net benefit between the two solutions varies depending on which path development takes. This is illustrated in the diagram below through a few selected parameters.

Net economic gain without costs of offshore wind power (present value, DKK billions)





BORNHOLM ENERGY ISLAND

2 or 3 GW of offshore wind power will be installed in the Baltic Sea off Bornholm and will be distributed through seabed power cables to Zealand and another country. The Bornholm Energy Island must be operational by 2030.

EXECUTIVE SUMMARY

Energinet's business case for the Bornholm Energy Island's electricity infrastructure gives decision makers and other interested parties a picture of the economic value of the energy island's electricity infrastructure and the specific solution which is preferred. It also sheds light on the implications for Energinet's corporate finances.

Together with the Danish Energy Agency's calculations for the overall profitability of the energy island, this business case will make up a significant part of the foundation for political decisions on the further development of the Bornholm Energy Island.

This executive summary first presents a quick overview of the energy islands and the political background and justification for establishing them in Denmark.

It also summarises Energinet's conclusions on the economic calculations for the Bornholm Energy Island's electricity infrastructure, and the recommended solution for the expansion of cables and electrical installations derived from these.

For more detailed information on finances, technical solutions and alternative scenarios, see the various sections in the business case.

Energinet's business case is the decision foundation for establishing electricity infrastructure for the Bornholm Energy Island, and must be approved by the Danish Minister for Climate, Energy and Utilities, pursuant to section 4 of the Danish Act on Energinet.

Energy islands in Denmark
A majority in the Danish Folketing has decided that two energy islands should be established in Denmark. One will be an artificial island in the North Sea. The other is Bornholm, which will serve as an energy island in the Baltic Sea.

What is an energy island?
An energy island is a place where large amounts of energy from offshore wind turbines can be pooled and transmitted to multiple countries via power cables on the seabed or converted to green fuels on the island and transported to other countries. The power cables can also be used to connect the electricity markets of the various countries.

BOX 1

CONCLUSION

Energinet's analyses show that the Bornholm Energy Island's electricity infrastructure is more cost-effective if power from the wind farms is transmitted to both Denmark and Germany, than if it is only transmitted to Denmark. Over the project's 30-year life time, a 9-figure net benefit is expected to be gained from a solution with a connection to Germany, compared to a solution without it.

Energinet emphasises that the calculations are subject to considerable uncertainty, as they are based on as yet uncertain assumptions. Energinet has to assess the isolated economic value of the electricity infrastructure that makes it possible to connect the power from the Bornholm Energy Island to electricity markets in one or more countries. The cost-benefit analysis therefore includes the value of the wind power, but not the costs of constructing the wind farms.

The necessary plant to convert the power from alternating to direct current can be established on the energy island. When the power has been pooled and converted to direct current, it can be transported over large distances without significant energy losses.

Value of energy islands in the green transition
The aim of the energy islands is to accelerate the expansion of renewable energy and ensure that far larger volumes of offshore wind power can supply all parts of society with green energy in the coming years, both in Denmark and in Europe, for the direct electrification of vehicles and heating, and to facilitate the production of hydrogen and green fuels for planes, ships and heavy industry, based on offshore wind power.

Energinet's role in the work with energy islands in Denmark
Energinet is responsible for developing, establishing and operating electricity cables between Denmark, the energy islands and other countries. Energinet must also establish and operate electrical installations on the islands, and connect the renewable energy from them to the onshore energy system.

As part of the preparatory and statutory environmental assessments, Energinet has also been tasked with performing preliminary environmental and seabed studies for both energy islands, the associated cables and offshore wind farms, and onshore installations.

Bornholm Energy Island
Bornholm Energy Island consists of plant at sea and on land. Plant at sea will consist of offshore wind turbines and associated cable grids, substations (if applicable) and cables to bring the power ashore on the south coast of Bornholm.

Submarine cables will be established from Bornholm to Køge Bugt on Zealand and to Germany initially, and possibly other partner countries later.

The onshore facilities on Bornholm will consist of underground cables and a new converter station in the south.

Under the plan, the converter station on Bornholm will support a 60kV connection to the local grid, and large-scale electricity consumption (eg Power-to-X) or generation (eg large PV power plants) in the vicinity will be able to draw or add power directly via the energy island infrastructure.

Possible locations for connecting power from the Bornholm Energy Island to the power grid on Zealand are at Solhøj in Ishøj or Høje-Taastrup Municipality, at Avedøre in Hvidovre Municipality or at Hovegård in Egedal Municipality.

On Zealand there will be underground cables and a converter station with a connection to the existing 400 kV high-voltage grid.

Bornholm Energy Island – a multi-country partnership
In extension of the Danish political decision to construct two energy islands in Denmark, the Danish and German governments have signed a political declaration of intent to investigate and identify possibilities for hybrid projects involving offshore wind power in the North Sea and Baltic Sea.

Energinet has signed a cooperation agreement with German 50Hertz on planning an interconnection between Denmark and Germany via the Bornholm Energy Island.

BOX 2

ENERGINET'S RECOMMENDATION

Energinet recommends making electrical connections to both Denmark and Germany from the Bornholm Energy Island, with two possible time schedules in mind.

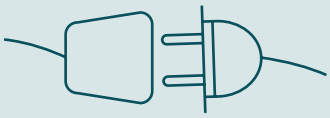
Two time schedules make it possible to fulfil the political goal of establishing offshore wind power at the Bornholm Energy Island before 2030, even if it proves to not be possible for the foreign partner to establish their connection to the energy island in time.

Energinet therefore recommends:

TIME SCHEDULE 1: Energinet, in cooperation with German TSO 50Hertz, establishes via the Bornholm Energy Island a 1.2 GW electrical connection between Zealand and Bornholm, and a 2 GW connection between Bornholm and Germany. All onshore and offshore electrical installations and interconnections between countries are ready for operation by the first half of 2029.

Or:
TIME SCHEDULE 2: Energinet establishes a 1.2 GW electrical connection between Zealand and the Bornholm Energy Island, which together with electrical installations in Denmark are ready for operation at the beginning of 2029. At the same time, Energinet and 50Hertz work jointly towards an expected future 2 GW interconnection between Bornholm and Germany, ready for operation in 2030 or as soon as possible thereafter.

BOX 3



CENTRAL ASSUMPTIONS

The economic costs and benefits have been calculated using the following central assumptions:

1. Establishment of 3 GW offshore wind power at the Bornholm Energy Island
2. High-voltage installations and cables must have enough capacity to transmit the connected offshore wind capacity to other locations
3. The Bornholm Energy Island is connected to a new substation at Solhøj on Zealand
4. The Bornholm Energy Island is developed in cooperation with 50Hertz
5. Technical solutions must allow more international connections and more capacity from offshore wind power
6. The Bornholm Energy Island will be a separate bidding zone from Zealand and Germany in the electricity market
7. In line with the political agreement of 1 September 2021, Energinet's net transmission costs will be transferred to the offshore wind farms
8. The 30-year investment horizon in the analysis from the date of commissioning is based on the expected concession period/lifetime for the offshore wind farms connected to the Bornholm Energy Island
9. Solutions exist which make it unnecessary to purchase reserves for outages on the connection between Zealand and Bornholm.

If the assumptions change, it may be necessary to recalculate parts of the business case on an ongoing basis.

50Hertz is a German TSO and Energinet's counterpart in Germany. The agreement involves planning a 2 GW interconnection that connects the Bornholm Energy Island wind turbines and the Danish electricity market with the German electricity market, and a 1.2 GW interconnection between Bornholm and Zealand.

The Bornholm Energy Island is thus an international cooperation on large-scale expansion of offshore wind power in the Baltic Sea, and has the potential to lead to more energy connections to other countries in the Baltic Sea (eg Sweden, Poland and the Baltic states) – possibly via more energy islands in the coming decades.

Connecting Bornholm Energy Island to Germany is most economic option

Energinet has conducted analyses of various interconnections to a future Bornholm Energy Island which are technically feasible.

These show that the Bornholm Energy Island offers a better economic solution if power from the wind farms is connected to both Zealand and Germany via a hybrid electricity connection (alternative 1 in this business case) than if the wind farms are only connected to Zealand (alternative 2).

A hybrid interconnection is a cable on the seabed that is used to bring power from the onshore wind turbines ashore, and also connect two countries' electricity markets.

Good economics means that the total economic benefits for generators and consumers in Denmark and Germany exceed the costs of establishing and operating the installations during their lifetimes.

Green power from the Bornholm Energy Island will displace fossil energy consumption in Denmark, Germany and other European countries – directly in existing electricity consumption and indirectly through the electrification of other sectors. The value to society of the Bornholm Energy Island's positive climate effects is also an important part of the cost-benefit analysis.

ENERGINET'S RECOMMENDATION TO THE MINISTER

Energinet recommends making electrical connections to both Denmark and Germany from the Bornholm Energy Island. Two possible time schedules for establishing this complete solution are also recommended.

Two possible time schedules allow the necessary time to fulfil the political goal of establishing offshore wind power at the Bornholm Energy Island before 2030, even if it proves to not be possible for the foreign partner to establish their connection to the energy island in time.

Energinet therefore recommends:

TIME SCHEDULE 1: Energinet, in cooperation with German TSO 50Hertz, establishes via the Bornholm Energy Island a 1.2 GW electrical connection between Zealand and Bornholm, and a 2 GW connection between Bornholm and Germany. All onshore and offshore electrical installations and interconnections between countries are ready for operation by the first half of 2029.

Or:

TIME SCHEDULE 2: Energinet establishes a 1.2 GW electrical connection between Zealand and the Bornholm Energy Island, which together with electrical installations in Denmark are ready for operation at the beginning of 2029. At the same time, Energinet and 50Hertz work jointly towards an expected future 2 GW interconnection between Bornholm and Germany, ready for operation in 2030 or as soon as possible thereafter.

The total budget framework for the Danish part of the project is the same in both scenarios, at DKK 16.9 billion in constant 2022 prices. In current prices, the budget is DKK 18.6 billion.

Conditions for the investment decision
Energinet's final investment decision is conditional on the following factors:

- That the authorities grant the necessary approvals to complete the project in the three countries affected: Denmark, Germany and Sweden (the power cable to Denmark has to be routed along the seabed through Swedish waters).
- 50Hertz makes the final investment decision for the German part of the project.
- For time schedule 1, that Energinet enters into binding establishment and operation agreements with 50Hertz for the Bornholm Energy Island project and associated connections.
- That the Danish Energy Agency enters into binding agreements with successful bidders for the construction of the offshore wind farms to be connected to the Bornholm Energy Island.
- That a decision is made on sharing of costs – between the wind energy generators' coverage of the costs of building and operating the electricity infrastructure (transfer of costs to wind power) and Energinet's tariff.
- Assurances that Energinet's future revenue caps will be adjusted in line with the realised costs, and that the transfer of costs to offshore wind turbine owners is approved as part of this.
- That suppliers and the market for technical plant (HVDC, cables etc.) are able to deliver the desired systems and components.

Political decisions
The project is a key element in the wider Bornholm Energy Island project in the Baltic Sea, including the installation of offshore wind power. The final framework for the Bornholm Energy Island will be decided by the Danish Parliament.

This includes the political decision about whether to connect additional offshore wind power at the Bornholm Energy Island, beyond the 2 GW decided under the climate agreement from 2020. This is the due to an addendum to the 2022 Finance Act on the construction of 2 GW of additional offshore wind power in Denmark by 2030.

In line with the political agreement of 1 September 2021, Energinet's net transmission costs will be transferred to the offshore wind farms as far as possible.

A political decision must also be made about whether to establish the Bornholm Energy Island in stages – first the plant on Bornholm and the connection to Zealand, and the interconnection to Germany later.

The recommendation on electricity infrastructure in this business case allows for the connection of up to 3 GW of wind power at the Bornholm Energy Island, as well as construction in stages. Staged construction must be coordinated such that more offshore wind power is not installed than can be transmitted via available connections.

In the event of any changes which significantly affect the design or costs of the recommended project, Energinet expects to re-apply for an updated section-4 approval from the minister. In this case, Energinet's supervisory board must also grant a renewed investment approval.

For an overview of political agreements etc., see the appendix on page 51.

Legal basis for Energinet to implement the project
The general mandate for Energinet's role in establishing energy islands in Denmark lies in the political agreement of 22 June 2020, which made the decision to establish two energy islands in Danish territory.

As the national TSO for electricity and gas in Denmark, Energinet is central to the realisation of the political goal for the energy islands, as Energinet is to own the general electricity infrastructure necessary to transport energy from the generation facility to the final consumer. Energinet therefore has a specific role and is named in the political agreement.

The general regulatory framework for Energinet's role in the energy island project is covered by Energinet's general purpose, pursuant to section 2(1) of the Danish Act on Energinet:

"Energinet's purpose is to own, operate and expand general energy infrastructure and perform related tasks, and thereby contribute to developing a climate-neutral energy supply. Energinet must consider security of supply, climate and the environment, and ensure open and equal access for all users of the grids and efficiency in their operation."

Pursuant to section 4 of the Danish Act on Energinet, the minister must approve the project in order for it to be implemented. This means that Energinet must obtain the minister's approval before construction can begin.

Approval by the minister is also a condition in order for costs related to the realisation and operation of the project to be regarded as necessary expenses under section 71 of the Danish Electricity Supply Act. Energinet notes that the actual costs of projects deemed necessary under section 71 of the Danish Electricity Supply Act will result in an increase in Energinet's revenue caps under the new financial regulation of Energinet that takes effect on 1 January 2023.

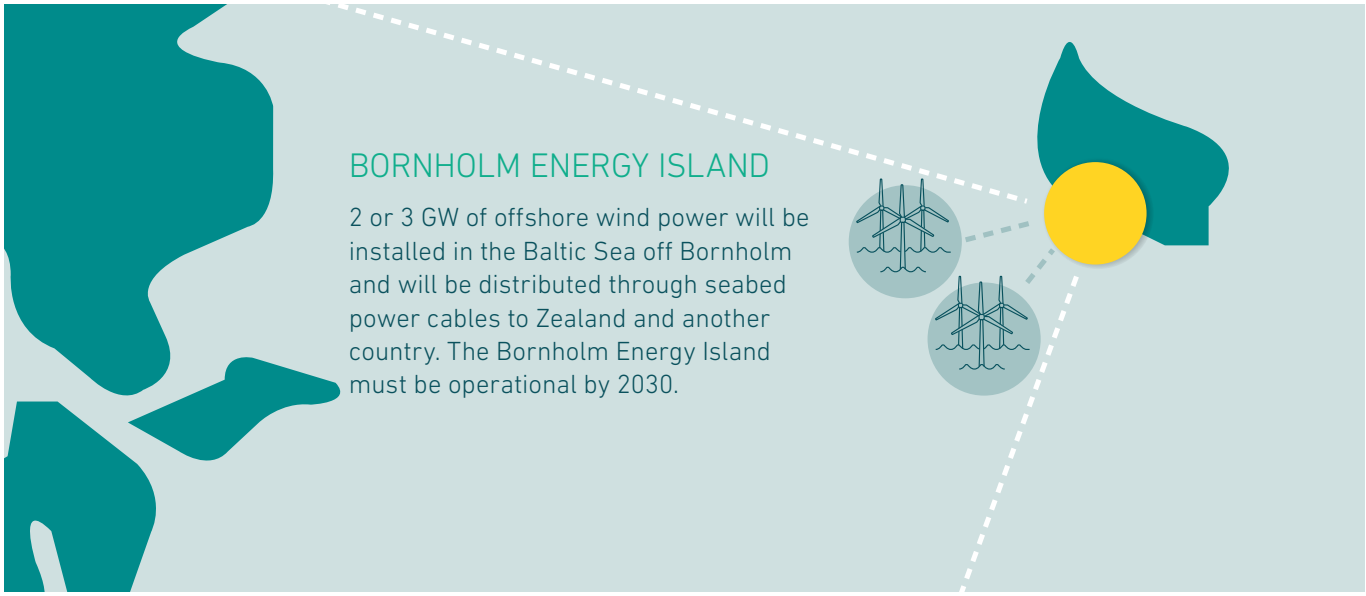
BOX 5

PART OF ENERGINET'S PLANS

The Bornholm Energy Island project, with 1 GW of landing capacity and 2 GW of offshore wind power, is included in the long-term development plan Energinet has to maintain pursuant to the Danish Act on Energinet. The long-term development plan was submitted for consultation in March 2022.

Electricity infrastructure for the Bornholm Energy Island is also part of Energinet's most recently approved investment plan.

BOX 4



BORNHOLM ENERGY ISLAND

2 or 3 GW of offshore wind power will be installed in the Baltic Sea off Bornholm and will be distributed through seabed power cables to Zealand and another country. The Bornholm Energy Island must be operational by 2030.

POLITICAL BACKGROUND TO THE BORNHOLM ENERGY ISLAND

This section briefly summarises the political decisions and agreements to date that form the basis for Energinet's work on the Bornholm Energy Island and hence this business case.

On 22 June 2020, a broad majority in the Folketing adopted the 'Climate agreement for energy and industry etc.' covering the establishment of two energy islands in Denmark – in the North Sea and the Baltic Sea. The aim of the energy islands is to ensure that Denmark can electrify more areas of society in the coming years, and to help ensure that the electricity consumption of all Danish households and businesses is met by green electricity.

Electricity from the energy islands can be exported to neighbouring countries and contribute to the green transition across Europe. Longer term, the energy islands must also allow the connection of technologies that can store or convert green electricity, for example into green fuels (via Power-to-X).

The Bornholm Energy Island consists of two wind farm sites near Rønne Banke and connected to Bornholm. Offshore wind power will be pooled on Bornholm. A high-voltage substation will convert the power from alternating to direct current and transmit it to Zealand and abroad via underground and submarine power cables.

The political agreement from June 2020 states that the Bornholm Energy Island must be established by 2030 and have a capacity of 2 GW offshore wind power. While negotiating the 2022 Finance Act, the Danish government and a number of parties in the Danish Parliament entered into a sub-agreement regarding establishment of an additional 2 GW of offshore wind power by 2030. A political decision to place 1 GW of the extra 2 GW at the Bornholm Energy Island is expected. The underlying assumption in this business case is therefore a total capacity of 3 GW offshore wind power at the Bornholm Energy Island.

In extension of the climate agreement of June 2020, the same majority in tthe Danish Parliament entered into a supplementary agreement in February 2021. The supplementary agreement states that "Energinet will establish, operate and own the public transmission grid and associated electrical installations connecting the energy islands to the Danish mainland and abroad". The agreement also states that binding agreements for the establishment of international power connections are desired, by the start of 2022.

The political sub-agreement on energy islands from September 2021 stipulates that Energinet's net costs of transporting electricity via the energy islands' cables and plant must, as far as possible, be passed on to the private players awarded the contracts for the offshore wind farms connected to the energy islands.

The political agreements describe energy islands as a paradigm shift from the traditional construction of standalone offshore wind farms. Large-scale offshore wind power will be connected to an energy island, from which power cables to Denmark and other countries will carry green power to consumers, while also serving as interconnections between electricity markets in several countries.

Energy connections between countries are thus a key element of the overall energy island projects. This vision means that the plant to be constructed on Bornholm must ensure the option of future expansion and connecting more countries longer term.

"With the establishment of the world's first two energy islands, we are embarking on a new era in the Danish wind adventure. We are hugely increasing the volume of offshore wind power, and will also make it possible to use the green power to fuel trucks, cargo ships and aeroplanes."

Dan Jørgensen
Danish Minister for Climate, Energy and Utilities
May 2020

CALCULATIONS WE HAVE MADE

This section provides a picture of what Energinet has calculated in this business case and the reasons behind this. In other words, which general solutions for the Bornholm Energy Island's electrical infrastructure have been compared and why these were chosen for the calculations.

Background
As mentioned above, the political agreements on energy islands from June 2020 and February 2021 stipulate that interconnectors to several countries are part of the rationale for establishing energy islands.

In cooperation with the Danish Ministry of Climate, Energy and Utilities, Energinet has therefore engaged in dialogue with governments and TSOs in other countries since autumn 2020, to explore international interest in an interconnection to the Bornholm Energy Island.

Ministers in Germany and Denmark have signed an agreement on energy cooperation in the Baltic Sea and North Sea, and Energinet and German TSO 50Hertz signed a joint declaration of intent to investigate a joint project on 18 January 2021.

Studies and analyses based on this initial declaration of intent were to be conducted to identify the possibilities for establishing a hybrid electricity connection between Zealand and Germany via the Bornholm Energy Island. A hybrid interconnection can connect the Danish and German electricity markets, while also supplying energy from offshore wind power to onshore grids.

Based on the promising results from initial investigations, Energinet and 50Hertz were able to sign a cooperation agreement on 23 November 2021. This agreement outlines the organisation and tasks, as well as outstanding issues for negotiation up until the establishment of a joint project. Negotiations about some conditions are still ongoing.

Purpose
Based on the political agreements on energy islands in Denmark and the agreements mentioned above between the Danish and German governments, and between Energinet and German TSO 50Hertz, the purpose of this business case is to assess the economics in the Bornholm Energy Island's electricity infrastructure.

Based on the Danish political agreements on energy islands, Energinet must identify the consequences of establishing and operating an international interconnection, and recommend a solution for connecting offshore wind power from the Bornholm Energy Island to the power grid in Denmark.

Energinet's calculations focus on two alternatives
Energinet has studied the possible effects of connecting offshore wind power to the Bornholm Energy Island and transmitting the electricity to Zealand and Germany over a 30-year analysis period.

This has essentially been done by comparing two alternatives. In one alternative, a 1.2 GW electricity connection to Zealand and a 2 GW interconnection to Germany (assumed to be owned by 50Hertz) are constructed. In the other scenario, a 3 GW electricity connection is built to Zealand, but no connection to Germany.

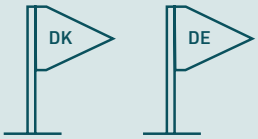
The cost-benefit analysis shows a positive net benefit from both alternatives, when the costs of the offshore wind power connected to the Bornholm Energy Island are not taken into account. The net benefit is considerably greater for the alternative that includes a connection to Germany. The section called 'How we made our calculations' explains the choices of capacity sizes for the interconnections etc.

The figure on the next page summarises the two alternatives.

The two alternatives have the following key common assumptions:

- Both alternatives are based on the establishment of 3 GW offshore wind power capacity.
- Both alternatives assume that plant will be built with a capacity corresponding to at least 3 GW of offshore wind power generation that is established at Bornholm.
- Both alternatives have the same expectations about technological development and future solutions.

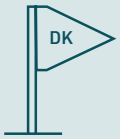
BOX 6



ALTERNATIVE 1: INTERCONNECTION TO ZEALAND AND GERMANY (DK + DE)

Alternative 1 (DK + DE) examines the economic effects of combining bringing offshore wind power ashore in Denmark with the possibility of exchanging energy between Denmark and Germany via the high-voltage plant on Bornholm.

It also examines possible derived consequences in the form of a greater need to reinforce the existing high-voltage grid in Denmark.



ALTERNATIVE 2: INTERCONNECTION TO ZEALAND (DK)

Alternative 2 (DK) examines the economic effects of only bringing offshore wind power ashore in Denmark via the high-voltage plant on Bornholm.

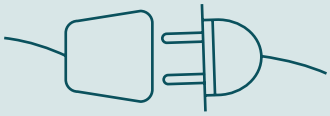
Alternative 2 is a methodological alternative and is not deemed to be realistic. This is in part because large volumes of wind power will be fed into Eastern Denmark, but there is no expectation that demand will keep in step with this increased supply.

It also examines possible derived consequences in the form of a greater need to reinforce the existing high-voltage grid in Denmark.

- No adjustments are made in the energy system modelling when extra production is added. This means that demand for electricity is held constant despite increased supply. This particularly impacts alternative 2, where large volumes of electricity are introduced on Zealand without greater demand.
- Both alternatives are flexible towards the connection of more offshore wind power, more connections to other countries, and the connection of Power-to-X plants or other innovative projects.
- In both alternatives, high-voltage installations are prepared for the possibility of connection on the alternating or direct current side. An extra interconnection to a third country will not require a new converter station on Bornholm if the direct current side is connected. However, this will be required if there is future expansion to the offshore wind power capacity.
- In connection with the environmental impact assessment of the plan for the Bornholm Energy Island, three possible sites have been identified for connecting power from Bornholm to the power grid on Zealand. Both alternatives assume the power is connected via a new high-voltage substation near Solhøj, which Energinet deems to be the best of the three sites. However, the final connection point will not be decided until later.
- Energinet believes it is technically possible to connect the local power grid on Bornholm to the Bornholm Energy Island without compromising stability or security of supply, and is working towards this. Both alternatives assume that such connection must be possible. In the unlikely event that connection is not possible, Energinet deems that this will not materially affect the results of the business case. The business case includes the necessary equipment to enable the Bornholm Energy Island to act as the 'power source' for the electricity grid on Bornholm.
- Both alternatives assume that the owners of the offshore wind turbines will be responsible for connecting power from the turbines to Energinet's high-voltage substation on Bornholm – following the same model as in the tender for the Thor offshore wind farm. If, during the tender process, it turns out that Energinet must handle the connection, this will mean higher capital costs than assumed in this business case.
- Energinet and 50Hertz have registered the Bornholm Energy Island with TYNDP 2022. This opens the door for the project to be selected as a 'Project of Common Interest (PCI)', making it possible to apply for funding from the EU's CEF[1] fund. It is likely that the Bornholm Energy Island will be eligible for EU funding, but to be conservative, this has not been included in this business case.

[1] CEF = Clean Energy Facility

BOX 7



STAGED CONSTRUCTION – OR NOT

There is still uncertainty about the time schedule for establishing the Bornholm Energy Island and the associated electricity connections to Zealand and Germany.

If a political decision is made to construct the Bornholm Energy Island in stages, eg first the 1.2 GW connection to Zealand and a matching volume of offshore wind power, and the connection to Germany and remaining volume of offshore wind power at a later stage, this is not deemed to change the fact that alternative 1 is better than alternative 2.

This is because the primary value created by the interconnections stems from the integration of wind energy generation at the Bornholm Energy Island. However, the capacity of the connected offshore wind must not exceed the combined capacity of the interconnections.

Staged construction is also not expected to add significantly to construction costs, as some of the investment would simply be pushed forward.

However, if construction is staged there will be a number of disadvantages when connecting to the existing system, such as outage time for existing plant when subsequent stages are constructed.

As a result of this outage time, it may be necessary to limit the wind power generation for the existing wind turbines connected to the Bornholm Energy Island. The outage time can be reduced by optimising the installation and test period for the new installation, but it is difficult at present to estimate possible costs.

ECONOMICS

This section provides an overview of the economic benefits of constructing the Bornholm Energy Island's electricity infrastructure in both alternatives, ie with and without an electricity connection to Germany.

There are many uncertainties associated with calculating the economic effects of plant where we do not yet know all the technical specifications, how costs will be shared, or how the energy sector and weather conditions in Denmark and Europe will develop over the coming decades.

Energinet has therefore tested the basic analysis with a number of alternative developments for fuel and CO_2 emission allowance prices, aims for the green transition etc. This section also provides an overview of some of the most notable insights from these calculations.

Overview of the economic effects of establishing the Bornholm Energy Island's electricity infrastructure
This business case evaluates the selected alternatives for the Bornholm Energy Island over a 30-year period, based on an investment analysis that includes a comparison of the net economic net gains and possible carbon reductions in Denmark and Europe.

The cost-benefit analysis includes the benefits from the total Bornholm Energy Island project and associated wind farms, but not the costs of the wind farms. It is therefore the difference between the economic value of the alternatives that is compared and is relevant to the investment decision.

The analysis cannot predict the profitability of the total Bornholm Energy Island. This will be covered in the Danish Energy Agency's future analyses of profitability.

The table overleaf provides an overview of the effects examined and estimated net benefits for the two alternatives.

Greatest benefit with connections to both Zealand and Germany
Alternative 1 (DK + DE) offers the largest economic benefit for Denmark. There are two primary reasons for this. Firstly, the value of the offshore wind power generation on the Bornholm Energy Island is deemed to be higher in this alternative, as alternative 2 supplies large volumes of electricity to Eastern Denmark without corresponding demand.

Secondly, under this alternative, Energinet and Danish society can share the costs of the electricity infrastructure with Germany.

Lower electricity prices for Danish consumers
In both scenarios, Danish electricity consumers will benefit from lower electricity prices due to the integration of the large volume of wind energy. Electricity prices in Eastern Denmark, in particular, will be reduced, and contribute to a significant consumer surplus in both scenarios.

The consumer surplus in the analysis only covers the consumer power in the electricity market. This means, for example, that a potential tariff effect or subsidy need for offshore wind turbine owners at the Bornholm Energy Island are not included in the consumer surplus in the analysis.

TABLE 1

RELATIVE DROP IN ELECTRICITY PRICES IN EASTERN DENMARK AS A RESULT OF THE BORNHOLM ENERGY ISLAND'S ELECTRICITY INFRASTRUCTURE

DKK/kWh

	Alternative 1 (DK + DE)	Alternative 2 (DK)
2030	0.03	0.08
2040	0.05	0.08

TABLE 2

Economic elements (present value in DKK billion)	Alternative 1 (DK + DE)	Alternative 2 (DK)
Economic benefits		
Generator surplus – Bornholm Energy Island	55.0	45.2
Generator surplus – existing producers	-18.2	-36.3
Consumer surplus	24.3	41.6
Congestion rents	0.2	2.2
Transit compensation	-0.1	-0.2
Emergency start-up	0.0	0.0
Properties required to maintain power system stability	0.0	0.0
Total economic benefits	**61.3**	**52.4**
Economic costs		
Construction costs	13.1	23.4
Operation and maintenance	1.7	2.7
Restoration, re-establishment	0.0	0.1
Reinforcement of existing transmission grid in Denmark	0.0	0.2
Ancillary services for handling concurrent outages on energy island cables between Zealand and Bornholm*	-	-
Ancillary services for balancing energy island offshore wind power*	-	-
Grid losses on international connections and the Great Belt Power Link	0.5	0.7
Financial loss due to outage resulting from breakdowns and maintenance	0.1	0.2
Load shedding due to concurrent outages on energy island cables between Zealand and Bornholm*	0.1	0.1
Total economic costs	**15.6**	**27.4**
Net economic benefits	**45.6**	**25.0**
Net economic gains with net tax factor	58.4	32.0

*See the section on the greater need for ancillary services on page 25.

However, Danish electricity prices will be lower in alternative 2 (DK), where electricity is only transmitted from the Bornholm Energy Island to Denmark. This is due to the large amount of offshore wind power being fed into the Danish electricity system in this scenario. There is thus a larger consumer surplus in the purely Danish scenario (alternative 2), even though this alternative yields a considerably lower economic benefit overall than alternative 1, which includes a connection to Germany. Lower electricity prices in both alternatives also lead to a drop in the producer surplus for existing energy producers.

Note that the analyses and the estimated drop in electricity prices derived from these assume all other factors remain constant. This means that derived or dynamic effects of lower electricity prices, such as a greater incentive to establish more PtX capacity, are not included in the analyses.

Demand draws power abroad

Energinet's analyses show that, in both scenarios, power from the offshore wind turbines at the Bornholm Energy Island will migrate abroad to a large extent. This is because electricity demand in Denmark is often insufficient to fully utilise the Danish wind power generation.

The present value of the total Danish trade gains is approx. DKK 8.8 billion higher for alternative 1 (DK + DE) than alternative 2 (DK). This shows that from a trading perspective, it is an advantage to have a direct connection to Germany from the Bornholm Energy Island, instead of transmitting all the electricity from the island to Zealand before distributing it to consumers in Denmark and abroad. Given current consumption patterns and existing interconnections from Denmark to Germany, the flow is also towards Germany.

Note that estimates of the economic effects are subject to considerable uncertainty. Trade gains, for example, are dependent on weather conditions, and the figures above are based on an average of 35 'climate years'.

Simulations show that the annual trade gains in alternative 1 (DK + DE) vary between DKK 3.5 and 6.5 billion in 2040, depending on the climate year.

Effects of significant alternative developments
In order to assess and examine whether calculations of economic benefits are robust in the face of various possible developments in the energy sector in Europe and Denmark, Energinet has compared the expected development (base case) with a number of alternative developments.

Table 3 overleaf summarises the economic effects of the Bornholm Energy Island's electricity infrastructure in the two alternatives, assuming a number of alternative developments. Some of the most notable insights are discussed under the table.

Having connections to both Denmark and Germany is most beneficial, regardless of alternative developments
In Table 3, the yellow column is highest in all alternative scenarios. This means that a solution involving connections to both Denmark and Germany yields the greatest economic benefits in all scenarios.

BOX 8

EUROPEAN TRADE BENEFITS

The Bornholm Energy Island will not only impact the Danish electricity system, as wind power generated on the island will be exported to other countries to a large extent in both alternatives. Alternative 1 (DK + DE) will lead to higher trade gains at European level than the isolated Danish trade gains. Under alternative 2 (DK), the Danish and European trade benefits will be close to identical.

The difference in the relative relationship between European and Danish trade gains for the two alternatives is due to the larger international sales capacity in alternative 1 (DK + DE). Sweden, Norway and France, in particular, will be adversely affected in both scenarios, while positive effects beyond Denmark will be seen particularly in Italy, Belgium, the Czech Republic and Poland. The German trade gains are slightly positive in both alternatives.

TRADE GAINS (PRESENT VALUE DKK BILLIONS)

	ALTERNATIVE 1 (DK + DE)	ALTERNATIVE 2 (DK)
DENMARK	**61.4**	**52.6**
EUROPE	**66.9**	**53.3**

TABLE 3

ECONOMIC EFFECTS OF THE BORNHOLM ENERGY ISLAND'S ELECTRICITY INFRASTRUCTURE

KEY INSIGHTS

Greater electricity consumption or higher prices for fuel or CO_2 emission allowances in Europe will magnify the economic benefits from the Bornholm Energy Island in both electricity infrastructure alternatives (DK + DE and DK), but especially for alternative 1 (DK + DE). The greater benefits are due to the fact that electricity prices in Europe will generally increase.

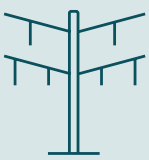
A more ambitious green transition in Europe will reduce the economic benefits of both alternatives, but especially for alternative 1 (DK + DE). A larger RE share in the European electricity system will reduce electricity prices across Europe, thus reducing the benefits of the Bornholm Energy Island.

More generation of renewable energy in Denmark will reduce the economic benefit from the Bornholm Energy Island in both electricity infrastructure alternatives (DK + DE and DK), but especially in alternative 2. Increased Danish RE production without a simultaneous increase in electricity consumption will depress electricity prices, reducing the benefits of the Bornholm Energy Island.

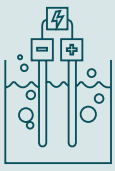
An accelerated green transition in the German electricity system will reduce the economic benefits of both alternatives, but especially of alternative 1 (DK + DE). The reduction in benefits is due to the fact that an increased RE share in the German electricity system will reduce electricity prices, including in Denmark.

The difference between the economic benefits of the two alternatives is reduced, to the relative benefit of alternative 2 (DK), when the electricity price across Europe is reduced. This is true whether a price reduction in Europe is due to more RE production, lower electricity consumption or a lower CO_2emission allowance price. This is because alternative 2 (DK) is less sensitive to changes outside Denmark.

Minor expansion to interconnections between European countries will reduce the economic benefits of both alternatives, but clearly for alternative 1 (DK + DE) the most, as this is more dependent on foreign sales. Less expansion to the electricity grid in Europe will mean less efficient utilisation of the electricity generated at the Bornholm Energy Island, reducing the benefits.



The difference between the economic benefits of the two alternatives is reduced, to the benefit of alternative 2 (DK), when electricity consumption in Denmark increases, for example for Power-to-X production. This is because alternative 2 (DK) is most sensitive to changes within Denmark.



Power-to-X plants and thus high electricity consumption on Bornholm will push up the electricity price on Bornholm and in the Eastern Denmark electricity system. Alternative 2 (DK) will benefit more than alternative 1 (DK + DE) from this, as Eastern Denmark is greatly oversupplied with wind energy from the Bornholm Energy Island in the base analysis.

CORPORATE FINANCE

This section presents the impacts of the Bornholm Energy Island's electricity infrastructure on Energinet's corporate finances in both alternatives, ie with and without a connection to Germany.

However, a number of unresolved issues will first be presented. These will have an impact on exactly how Energinet's financial situation is affected.

New financial regulation of Energinet
As of 1 January 2023, the Energinet companies with TSO obligations are expected to switch from the current break-even principle to a revenue cap regulation. The new financial regulation will set a revenue cap for each company, consisting of an expense and a yield cap. The yield cap is to compensate Energinet for transferring risk from consumers to itself.

Essentially, the new financial regulation entails a greater risk that Energinet will be financially responsible for budget overruns in the construction of the Bornholm Energy Island's electricity infrastructure. If the Danish Utility Regulator accepts that the revenue cap can be adjusted with the realised costs, Energinet will not bear the same financial risk.

If the revenue cap is adjusted with the realised costs, it will ultimately be the electricity consumers who are impacted by any deviations from the budget. Without a post-adjustment, budget deviations will impact Energinet's equity.

The system operator's conditions for the revenue cap are quite different from those of the transmission companies, as the system operator does not normally receive broader financing for operations even if more electricity connections are commissioned. However, the system operator must prepare a business plan to serve as a basis for the addition to the expense cap. In order for the system operator to be able to perform tasks related to system operation and development and the market in a future with energy islands as part of the electricity system, it is essential that supplementary funding can be obtained via the business plan, corresponding to the increased complexity and volume of work which the energy islands will introduce, both before and after commissioning. However, these expenses are not currently part of this business case.

The specific aspects of this risk will not be known until the final conditions of the revenue cap regulation have been decided. It is therefore still unclear how the new regulation will specifically affect Energinet when large innovation projects such as energy islands are established.

BOX 9

ENERGINET'S NET EXPENSES

It remains to be clarified what can be included in Energinet's net expenses, but it is expected that Energinet's net transmission expenses will consist of:

+ Depreciation on Energinet's share of the investments (less any EU grants)
+ Adjusted return on Energinet's investments
+ Operating expenses for transmission plant on the energy island
+ Grid loss expenses associated with bringing electricity ashore from the energy island
÷ Energinet's share of congestion rent from interconnections to other countries via the energy islands.

Transfer of Energinet's net expenses
The political sub-agreement on energy islands from September 2021 stipulates that Energinet's net costs of transporting electricity via the energy islands' cables and plant must, as far as possible, be passed on to the private players awarded the contracts for the offshore wind farms connected to the energy islands.

The agreement does not specify how this transfer is to be implemented. Energinet will work with the Danish Energy Agency and the Danish Ministry of Climate, Energy and Utilities to jointly prepare a method for transferring Energinet's net costs.

Sharing ownership and expenses between Energinet and 50Hertz
Energinet and 50Hertz are currently negotiating how ownership and costs should be distributed between the two companies in alternative 1 (DK + DE). The principles for allocating costs and congestion rent for the electricity connection between Zealand and Germany via the Bornholm Energy Island have still not been finalised. Table 4 shows the assumptions about ownership and cost allocation between Energinet and 50Hertz. In this business case, it is assumed that transmission losses and congestion rent for the project are shared 50/50 between Energinet and 50Hertz.

Overview of corporate finance
Even though Energinet's net costs for the construction and operation of the Bornholm Energy Island's electricity infrastructure are transferred to the offshore wind turbine owners, the energy island will most likely have derived impacts on Energinet's corporate finances which are not covered by the cost transfer to the offshore wind turbine owners.

For example, congestion rents and transmission losses on existing interconnections to other countries will be affected. Connecting power from the Bornholm Energy Island's offshore wind turbines may also lead to larger imbalances, increasing the need for Energinet to purchase various ancillary services. Finally, the electricity connections from the Bornholm Energy Island may lead to greater losses in the Danish transmission grid, and possibly to a need to reinforce the power grid, leading in turn to more expenses for Energinet as a company.

Construction costs
Energinet estimates that construction costs for Energinet will be approx. DKK 10 billion lower in present value for alternative 1 (DK + DE) than for alternative 2 (DK) . This is because 50Hertz will bear a significant share of the construction costs for the interconnections from the Bornholm Energy Island in alternative 1 (DK + DE), while Energinet and Danish society will bear all the costs in alternative 2 (DENMARK). In alternative 2, the plant must also be divided into three separate connections – three extra, independent cable systems of 1 GW each. The additional division into independent connections is necessary in order to meet the Danish security of supply criterion for N-1.

Congestion rents
Energinet's model calculations show that the total Danish congestion rent is lower in alternative 1 (DK + DE) than in alternative 2 (DK). This is because adding 3 GW of offshore wind power from the Bornholm Energy Island in alternative 2 (DK) will have a positive effect on the total congestion rents for existing Danish international connections and the Great Belt Power Link.

Alternative 1 (DK + DE) will result in positive congestion rents for the two new interconnections from Zealand and Germany to the Bornholm Energy Island, but will also reduce the total congestion rents for the existing Danish international interconnections and the Great Belt Power Link.

Uncertainty about congestion rents
The simulations of the electricity market upon which estimates of congestion rent are based are subject to uncertainty. An important assumption for market simulation is the climate year used as the basis for the calculations. The results in the corporate finance and economic analysis are based on an average of 35 climate years, but the congestion rents vary considerably for the simulated climate years.

TABLE 4

Breakdown of expenses

Construction and operating costs	
Zealand-Bornholm	Energinet owns, operates and incurs all operating expenses on the connection from Zealand to Bornholm
Bornholm-Germany	50Hertz owns, operates and incurs all operating expenses on the connection from Bornholm to Germany
Installations on Bornholm	Energinet owns, operates and incurs all operating expenses for plant on Bornholm

BOX 10

UNCERTAINTIES ASSOCIATED WITH CONSTRUCTION COSTS

There are a number of general uncertainties in the budget regarding construction costs, eg:

- New technology must be built on an island (immature technology, transportation of materials, manpower requirements, etc.)
- The way costs will be shared between Energinet and 50Hertz
- Uncertainty about the connection point on Zealand
- Costs of any delays
- Uncertainty about acquisition terms.

TABLE 5

Corporate finance elements (present value in DKK billion)	Alternative 1 (DK + DE)	Alternative 2 (DK)
Corporate finance costs		
Construction costs	13.1	23.4
Operation and maintenance	1.7	2.7
Restoration, re-establishment	0.0	0.1
Reinforcement of existing transmission grid in Denmark	0.0	0.2
Ancillary services for handling concurrent outages on energy island cables between Zealand and Bornholm*	-	-
Ancillary services for balancing energy island offshore wind power*	-	-
Grid losses on international connections and the Great Belt Power Link	0.5	0.7
Financial loss due to outage resulting from breakdowns and maintenance	0.7	1.1
Total corporate finance costs	**16.0**	**28.2**
Corporate finance benefits		
Congestion rents	0.2	2.2
Transit compensation	-0.1	-0.2
Emergency start-up	0.0	0.0
Properties required to maintain power system stability	0.0	0.0
Transfer to electricity generators and consumers	16.0	26.2
Total corporate finance benefits	**16.0**	**28.2**
Net corporate finance benefits	**0.0**	**0.0**

*See the section on the greater need for ancillary services on page 25.

UNCERTAINTY ABOUT A GREATER NEED FOR ANCILLARY SERVICES

Energinet procures a number of services in order to maintain a reliable and stable electricity system all year round. These are referred to as ancillary services. The Bornholm Energy Island will affect the need for ancillary services due to two factors that could arise: 1) The possibility of a dimension-setting fault (also called an N-1 outage) in the Eastern Denmark power system will increase following the establishment of the Bornholm Energy Island, and 2) offshore wind power at the Bornholm Energy Island is expected to increase the need for ancillary services to handle imbalances in the electricity system.

Both the increased need for ancillary services due to the Bornholm Energy Island and, in particular, the price of ancillary services in the future are subject to great uncertainty.

The extra complexity and greater need to balance the electricity system that result from adding a large unit such as an energy island must be considered in the development of the future European balancing platform and in the Nordic markets for reserves. Work is therefore being done to analyse how Energinet and other TSOs can ensure the efficient utilisation of ancillary services across borders.

Ancillary services for a possible outage on the connection to the Bornholm Energy Island

Energinet currently purchases ancillary services (mFRR) to be able to handle a dimension-setting outage (N-1) of 600 MW in Eastern Denmark. Under both alternatives in the business case, the dimension-setting outage will potentially increase following establishment of the Bornholm Energy Island. In alternative 1 (DK + DE), the dimension-setting outage doubles to 1,200 MW. This can occur if both cables from the Bornholm Energy Island to Zealand drop out at the same time and this is considered a dimension-setting fault.

In the business case it has been assumed that Energinet will not increase its purchases of ancillary services to handle simultaneous outages on both cables from Zealand to the Bornholm Energy Island. This assumption has been based on a risk analysis and acceptance of a greater risk of load shedding if there is an outage. The risk analysis shows that, on average, approx. 0.4 outage minutes can be expected in Denmark in 2030, while approx. 0.6 extra outage minutes can be expected in 2040. The economic costs associated with this are shown in Table 2, under 'Ancillary services for handling simultaneous outages on the energy island cables between Zealand and Bornholm'. Note that if an outage occurs, there will be a large number of extra outage minutes in the given year.

The approach of accepting load shedding and not purchasing reserves has to be accepted politically and by the other Nordic TSOs.

If the load shedding solution is not accepted, additional ancillary services will have to be purchased in Eastern Denmark to handle outages. The costs associated with this are highly uncertain and depend on the future framework for the purchase of ancillary services. In alternative 1 (DK + DE), the costs can be expected to be in the range DKK 150-1,250 million annually. The high end of the estimate reflects an extreme case with historically high prices for ancillary services.

Ancillary services to handle balancing of offshore wind power

Establishing extra wind generation capacity (eg 3 GW of offshore wind power at the Bornholm Energy Island) will generally increase Energinet's need to purchase ancillary services (FCR-N, FCR-D, FRR, aFRR, and mFRR) to handle potential imbalances in the Danish electricity system in line with current regulations and operating agreements. The greater need for ancillary services is due to the expansion of offshore wind power. Irrespective of whether the offshore wind power is established in connection with the Bornholm Energy Island or elsewhere in Denmark in a traditional radial connection, such as the Thor offshore wind farm, Energinet would need to purchase more ancillary services. Since the costs of ancillary services can be attributed to the expansion of offshore wind power and not Energinet's electricity infrastructure, they have not been included in the business case.

Based on the current market framework and historical prices, Energinet's preliminary analyses estimate the cost of these ancillary services at approx. DKK 650 million annually. The costs of ancillary services to handle balancing are very uncertain, and changes in a range of factors can affect costs differently.

It will be a major task for Energinet in the coming years to complete the development work necessary to allow the power system to be effectively balanced in a future with large expansion to offshore wind power.

CLIMATE, RENEWABLE ENERGY AND SECURITY OF SUPPLY

This section discusses the consequences Energinet believes the operation of the Bornholm Energy Island's electricity infrastructure will have on the climate, on the ability to integrate more renewable energy and on security of supply in both alternatives (DK + DE and DK).

Climate impact
Both alternatives will result in significant carbon reductions from the electricity sector at European level. This is because the large amount of offshore wind power from the Bornholm Energy Island incorporated into the electricity system in the two alternatives will lead to a smaller share of electricity generation based on fossil fuels than would otherwise be the case.

Carbon emissions from electricity generation
Carbon emissions from Danish electricity generation are expected to be very limited already in 2030, and the expected Danish carbon reductions in the electricity sector from the project are therefore small. Potential reductions in other sectors and carbon emissions during the construction phase are not included in the carbon reduction figures in the table below.

Alternative 1 (DK + DE) will lead to the largest total carbon reductions in Europe, as large volumes of fossil electricity generation on the European continent will be displaced by having a direct connection from the Bornholm Energy Island to Germany.

Carbon emissions from production and the construction process
Production of building materials for the Bornholm Energy Island, like the construction process itself, will result in carbon emissions. It is not possible at present to describe the Bornholm Energy Island's impact on the climate during the construction phase – for either alternative 1 or 2.

However, Energinet would like a special focus on reducing the energy consumption and carbon footprint during the construction process. Energinet will therefore asses the measures that can be taken to reduce the climate impact during the construction phase most effectively, such as:

- Preparing climate accounts and goal management for carbon emissions during the project
- Prioritising electricity-powered construction sites and machine parks
- Reducing materials and waste.

Assessment of the climate impact during the construction process is expected to be carried out in parallel with the environmental assessment processes.

TABLE 6

Change in CO2 emissions from electricity production (million tonnes)	Alternative 1 (DK + DE)	Alternative 2 (DK)
2030		
Denmark	0.04	-0.07
Europe	-3.5	-2.2
2040		
Denmark	0.04	-0.06
Europe	-3.1	-2.2

Integrating renewable energy
Both alternatives examined will contribute to integrating electricity from the offshore wind turbines at the Bornholm Energy Island into the Danish and European power system.

Integrating renewable energy refers to the entire electricity system's ability to transport the volumes of renewable energy that wind turbines and PV power plants are able to generate to consumption centres at times of demand.

Curtailment of renewable energy refers to potential electricity generation (from sun and wind) that is not generated because supply exceeds demand in certain hours.

Alternative 1 (DK + DE) will allow greater utilisation and generation of renewable energy in Denmark and Europe than alternative 2 (DK), as shown in the table below.

Note that in both alternatives, the entire potential electricity generation (about 13.8 TWh per year) from offshore wind power at the Bornholm Energy Island cannot be integrated into the electricity system under current assumptions about expected consumption in Denmark and Europe.

Curtailment of renewable energy will increase both in Denmark and neighbouring countries (primarily Germany) once the Bornholm Energy Island is established. The integration of renewable energy is therefore also less in Europe than in Denmark in isolation.

Security of supply
Energinet believes that the additional electricity generated from wind power at the Bornholm Energy Island will only have a marginal positive impact on generation adequacy in Denmark. This is because it is typically at times with relatively low production of wind power that the risk of generation inadequacy is highest.

Alternative 1 (DK + DE) is expected to have a greater positive impact on Danish generation adequacy than alternative 2 (DK). This is because alternative 1 (DK + DE) offers an extra import possibility from Germany to the electricity system in Eastern Denmark, which is expected to see an increasing risk of generation inadequacy, especially after 2030.

The Bornholm Energy Island may potentially increase the dimension-setting unit (N-1) in the Eastern Denmark power system. This will increase the risk of power outages. The handling of the increased risk to security of supply is described in the section on the greater need for ancillary services on page 25.

No quantitative analyses of generation adequacy have been conducted for the two alternatives, but it appears from Energinet's Security of Electricity Supply 2021 report that the two Danish energy islands will have a positive effect on Danish generation adequacy.

TABLE 7

Integration of renewable energy from wind and sun (TWh)	Alternative 1 (DK + DE)	Alternative 2 (DK)
2030		
Denmark	13.3	12.8
Europe	12.5	12.1
2040		
Denmark	13.1	12.8
Europe	12.2	11.8

ENVIRONMENT, SAFETY AND EMERGENCY PREPAREDNESS

Environment
The overall plan for the Bornholm Energy Island and the stand-alone project are subject to the Danish Environmental Assessment Act.

By order of the minister and under the management of the Danish Energy Agency, Energinet has been tasked with performing preliminary studies and environmental assessments of the overall government plan for the Bornholm Energy Island.

Energinet is also responsible for building the electricity infrastructure for the energy islands (high-voltage substations and cables), and as owner of the specific installations, Energinet is responsible under the Danish Environmental Assessment Act for preparing environmental impact assessments for these installations.

The Danish Environmental Protection Agency will be the approving authority for the entire EIA process (all land installations and submarine cables) for the Bornholm Energy Island. Local authorities will normally also be the approving authority for relevant local plan processes (addendums to municipality plans and local development plans).

The environmental assessments ensure a high level of environmental protection and contribute to the integration of environmental considerations in all elements of the Bornholm Energy Island by involving the public.

The processes for assessing and taking the expected environmental impacts of the Bornholm Energy Island into account have been initiated and are expected to be completed in mid and late 2023, respectively, in line with the legislative framework.

It is therefore not possible at present to describe the impact of the Bornholm Energy Island's electricity infrastructure on the environment – for either alternative 1 (DK + DE) or 2 (DK). It is therefore not yet possible to estimate the costs associated with reducing the environmental impacts, other than what follows from the costs of undertaking the general regulatory and planning process.

Health and safety
Energinet is planning to construct the Bornholm Energy Island's electricity infrastructure with significantly fewer occupational injuries involving absence than is normal for a construction project, and no serious occupational injuries. Serious occupational injuries are defined here as injuries with permanent impacts or that result in more than five weeks absence from normal work.

This goal requires that the project builds on Energinet's accident prevention and that management gives high priority to health and safety and a safe culture.

For an average construction project at Energinet, there are 10 occupational injuries resulting in absence of the employee due to the injury for every 1 million working hours. For both alternatives, it is therefore expected that there will be more occupational injuries, the higher the level of activity.

Energinet will therefore prepare a separate health and safety strategy for the Bornholm Energy Island's electricity infrastructure, with a special focus on reducing the number and severity of occupational injuries in the construction process.

The health and safety strategy must provide a solid framework for proactive and forward-looking health and safety initiatives, and contain specific action plans for reducing negative health and safety impacts in all parts of the project, from maturation to operation, such as:

- Introducing health and safety qualification of project products, eg during design, procurement, appointments etc.
- High weighting of contractors' initiatives to prevent accidents
- Planning contractor audits to check they are fulfilling the health and safety considerations that had a positive weighting in the award of the contract
- Preparing a project-wide mandatory introductory programme for a safety climate.

The number of occupational injuries involving absence and serious occupational injuries for this project are expected to be proportionally lower than for Energinet's other major construction projects.

However, the project will lead to so much activity involving risk that the absolute number of occupational injuries is expected to increase, compared to if the Bornholm Energy Island was not established.

Emergency preparedness
Energinet must perform the necessary planning and take the necessary steps to secure supply in emergency and crisis situations.

The Bornholm Energy Island's electricity infrastructure is of such a size and nature that its establishment is expected to impact on Energinet's robustness in the face of emergency incidents (ie sudden, undesired and abnormal incidents which affect Energinet's part of security of supply or plant, personnel or environment safety).

It is therefore necessary for Energinet to prepare an emergency preparedness impact assessment in line with the Danish Electricity Sector Emergency Management Act, with the aim of reducing vulnerability to emergency incidents.

In order to be able to prepare the emergency preparedness assessment, a specific description of the technical plants is required, ie the physical dimensions and properties of the plants and where they will be located.

Energinet will, as soon as possible, assess and consider the robustness of the construction work in the face of emergency incidents.

RISKS

Bornholm Energy Island is to become world's first energy island. The innovation bar has been set high, and the decisions bound by the climate agenda add an external time pressure for the project. The Bornholm Energy Island's electricity infrastructure is therefore a project that carries high risk.

The finances and time schedule also depend on the collaboration with 50Hertz on the interconnection to Germany, and the specific solutions will be based on new technology that must continue to be developed and mature. When it is time to buy the components, we also risk finding the market is already overheated due to the similar ambitious green transition in our neighbouring countries.

The business case for the Bornholm Energy Island's electricity infrastructure is therefore based on a broader span of assumptions than normal. This increases the total risk for the project's time schedule, budget and technical solutions.

Energinet has worked on the project's risks and possible mitigating measures in line with Energinet's risk policy and general risk framework tools. Based on the risk analyses, reserves (uncertainty costs) of almost DKK 4 billion have been allocated. See Table 9 in the appendix on *Construction budget and derived operating costs* regarding the construction budget. The uncertainty costs consist of a project manager reserve, a steering committee reserve and a risk pool, and correspond to 30% of the core budget (excluding construction loan interest). This is around 20 percentage points higher than what Energinet usually allocates to risks in major construction projects. Uncertainty in relation to budgeting the various items is covered by the steering committee and project manager reserves, while the risk pool is based on risk of additional costs beyond this budget uncertainty.

The risk pool has been calculated based on an assessment of the consequences and probabilities of the identified risks, with the aim of ensuring that the project can prevent (mitigate) foreseeable risks and potentially also cover the derived costs of risks that are actually realised. The risk pool is dynamic and reflects the current risk picture. Relevant risks will thus be assessed and efforts continually made to mitigate them as the project moves forward.

The key risks, deemed to have the greatest financial or temporal impact on the business case, are shown in the risk matrix and table below. The financial consequences have been assessed based on corporate finance criteria. Assessment of each risk in the risk matrix is based on the probability and consequence (after planned mitigating measures).

The risks that potentially have the greatest financial consequences for the project are, in particular, 1) technical risks related to the development of HVDC standards and technology and interconnection with Bornholm's electricity system. Thereafter, 2) the risk of unforeseen market conditions and overheating (eg in the light of developments in Ukraine) and (3) other external factors that may delay the project, such as environmental assessment processes. Finally, there is a risk 4) of a change to the division of ownership for the cable to Germany and 5) that Energinet cannot get insurance for offshore construction work.

In addition, there are a number of risks that are deemed to have a slightly lower financial impact, but will impact on the process, or for which the economic consequences may be significant. These include the risk that Energinet's partner, 50Hertz, is delayed or unable to commit to the project in time, uncertainty about the chosen market design (offshore bidding zones), connection of PtX plants or offshore wind power, and the assumption that Energinet's net costs can be passed on to offshore wind turbine owners or consumers.

Finally, the business case is based on the assumption that Energinet does not increase purchases of ancillary services to handle simultaneous outages on energy island cables between Zealand and Bornholm, and thus implicitly accepts a higher risk of load shedding (see the explanation on page 25 under 'Uncertainty about a greater need for ancillary services'). This involves an economic cost of potential outages, which has, however, been included in the business case. Similarly, costs of downtime in the event of outages, for example of submarine cables or substations, or disruptions between the systems, are included in the business case. The risk of outages and a greater need to purchase (or changes to prices for) ancillary services to handle outages and balance more wind power are therefore not shown in the risk matrix. A number of mitigating measures are being implemented to reduce these risks.

The key risks have been placed in the risk matrix based on their assessed probability and consequence (after mitigating measures have been implemented).

ID	Risk
R097	**Environmental assessment processes etc. delay the project** The project has been planned according to a tight time schedule with no room for delays. If the project is delayed or put on hold for an extended period, for example due to environmental assessment processes or other external conditions in the construction phase, this may result in additional requirements from contractors. To reduce the risk, the project will prepare a solid procurement strategy and include delay clauses in contracts to reduce the consequence.
R006	**Development of HVDC standards and technology** Technologies for converting and transmitting direct current at high voltages are not mature. If development work cannot be completed in time and tender documents thus cannot be prepared with sufficient quality, this may lead to rejection by contractors, higher costs and a lack of competition. Energinet is seeking to reduce this risk by participating in international development work, preparing a robust procurement strategy, purchasing an HVDC simulator etc. Given the tight schedule for the energy island, the probability that the necessary development work cannot be completed in time is deemed to be relatively high. The consequence is also deemed to be relatively high, as defects in the technical specifications may result in components and control systems having to be redesigned during commissioning, which may further lead to delays for the offshore wind power.
R102	**Risk of unforeseen market conditions** Following completion of the budget and associated uncertainties for the project, there has been a strong focus on phasing more renewable energy into the European energy supply as quickly as possible. This is putting added pressure on supply chains, such that the price of transmission systems may rise considerably. It is difficult to estimate the probability and consequences of this, as they are interdependent, but the risk calculation assumes a major consequence (> DKK 500 million) with a probability of around 20%.
R101	**Energinet cannot take out insurance for offshore construction work** The business case assumes that Energinet can take out insurance covering the entire construction work. However, insurance companies are signalling that they will not insure the offshore construction work, which means the project would have to cover any damage during offshore construction. For the project, damage to submarine cables, eg when laying and protecting, will entail considerable repair costs. Energinet is seeking to reduce this risk through dialogue with the market and adjustment to the project's insurance strategy.
R087	**Change in division of ownership for the cable to Germany** The business case assumes that 50Hertz owns and finances the connection from the Bornholm Energy Island to Germany. If the negotiations with 50Hertz do not proceed as expected, ownership of the international connection might alternatively be shared 50/50 or split at the EEZ boundary at sea. This would mean that the project has to bear some of the costs of the connection to Germany.
R065	**Interconnection with Bornholm's electricity system** Connecting the energy island's large generation units to Bornholm's small electricity grid is a technical challenge. Together with contractors, a solution must be developed which ensures the necessary security of supply and power quality on Bornholm. The business case assumes the interconnection can be completed with a number of budgeted initiatives. However, there is a risk that the contractors will be unable to implement the interconnection within the budgeted funds, and new and more expensive solutions may have to be implemented. This could be the costs for a converter station to separate the energy island from the local system, or a new ancillary services unit on Bornholm. Energinet is seeking to reduce this risk through analyses of the consequences of connecting the local electricity system, and dialogue with HVDC suppliers on the development of technical solutions. The probability is deemed to be relatively low, as the initial dialogue with suppliers suggests that solutions can be developed. However, the possible financial consequences are relatively high, as investments must be made in new plant to resolve technical problems if the challenges cannot be solved with the expected solution.
R086	**Uncertainty about connection requirements for PtX plants** The business case assumes that it must be possible to connect PtX to the energy island. Given that PtX has not yet been established on a large scale, there is great uncertainty about the technical design and operation of such plants. This applies to physical factors such as voltage level, number of cables etc., but also to operating patterns and technical performance. Connecting PtX could therefore result in increased demands on the energy island's control system and extra electrical plant to ensure stable operation. This risk is being mitigated by Energinet continuously monitoring technology developments and connection conditions for PtX, and being in dialogue with suppliers of transmission systems, so that the design of the Bornholm Energy Island's electricity infrastructure can match the expected future requirements as far as possible. The probability that requirements for the connection of PtX plants are unclear beforehand is deemed to be high, but the potential financial consequences are deemed to be limited.

ID	Risk
R051	**Change in acquisition process for construction in stages** If the partner TSO cannot make a decision on acquisitions in time, this may result in the purchase of HVDC converters having to be split across several contracts, rather than being grouped in one. This can lead to greater complexity, uncertainty about the division of responsibility when connecting electricity at the plant, delays and higher costs. To reduce this risk, Energinet is participating in international development work on interoperability and preparing a robust acquisition strategy, and will include 50Hertz in the technical discussions, even if the project is realised through construction in stages. The financial consequences are deemed to be limited, but with a medium-high probability.
R021	**Partner TSO is delayed** Lack of regulatory approvals or political decisions in Germany or failure of Energinet and 50Hertz to agree on financial conditions could lead to 50Hertz not committing to the project in time, which could delay the overall project. Effort is being made to reduce this risk through carefully planned time schedules and the recommendation option of completing the project with staged construction as an alternative time schedule. The consequences could still be financial impacts, but are less likely to occur.
R079	**Transfer of Energinet's offshore wind power costs** There is a risk that Energinet will not be able to cover all the costs of the Bornholm Energy Island's electricity infrastructure, if Energinet's net costs cannot be passed on to the offshore wind turbine owners or consumers and Energinet is held responsible for realised costs. This risk is being mitigated by Energinet making it clear to the authorities that it is vital that Energinet be able to adjust the revenue cap if the actual costs exceed the budget. This will be a key point in discussions with the Danish Utility Regulator on transferring Energinet's net costs for offshore wind power. The consequence for Energinet's finances is therefore deemed to be limited, but there is a moderate risk of it occurring to some extent.
R025	**Development of market design** If neighbouring countries object to a national bidding zone process, this could lead to delays and uncertainty, or to a decision not to establish an independent offshore bidding zone – which is what Energinet recommends. This could result in delays to the project and poorer economics than otherwise. This risk is being mitigated by Energinet engaging in dialogue with authorities to ensure that offshore bidding zones are market designed. Energinet is also contributing to European bidding zone studies that can support a recommendation for offshore bidding zones when establishing energy islands. If this risk is realised, it could have significant consequences for the time schedule and thus the overall project economics.
R078	**Connection conditions for offshore wind power** There is a risk Energinet may have to pay compensation to wind power developers if the offshore wind turbines cannot be connected to the electricity grid at the agreed time. This risk is being mitigated by designing the connection agreement to ensure sufficient flexibility for Energinet in relation to the connection period, reasonable uptime targets after commissioning, and qualifications regarding capacity limitations on the international connections, which are beyond Energinet's control. The consequence and probability after mitigating measures are therefore deemed to be limited.

OPPORTUNITIES AND CHALLENGES FOR ENERGINET'S REPUTATION

If we examine the potential effects of the Bornholm Energy Island on Energinet's reputation, there are clear opportunities as well as challenges.

The energy islands are one of the largest construction projects in Denmark's history, and the Bornholm Energy Island could become the world's first operational energy island.

The rationale for the energy islands is a green transition, at a time when the climate agenda has become ubiquitous in public debate – among politicians, citizens and businesses.

Given this situation, it is clear that the Danish energy islands will receive a lot of interest and in-depth attention from citizens and landowners near the planned infrastructure for the energy islands, municipalities, professional opinion-makers, think tanks, green organisations and companies with an economic interest in being part of the projects.

The Bornholm Energy Island thus gives Energinet many opportunities to become more publicly known and be connected with and held responsible for processes related to the progress and rationale of the energy islands. Energinet's work with the Bornholm Energy Island's electricity infrastructure could therefore potentially have either a positive or negative impact on Energinet's reputation.

The primary aim of strategic communication and managing interests in Energinet's work with energy islands in general and specifically with the Bornholm Energy Island, is to support the realisation of the energy islands, and specifically the electricity infrastructure at the core of the energy islands which Energinet must build, own and operate – and thus have lasting responsibility for.

Since offshore wind power and energy islands are associated with green energy, positive progress is expected to contribute to enhancing Energinet's general reputation. Conversely, delays, budget overruns or mistakes that are connected to Energinet could have a negative impact on Energinet's reputation, whether or not the causes are directly related to Energinet's responsibility in the complex energy island project.

Even though Energinet thus expects direct proportionality between progress on the Bornholm Energy Island in general and a positive impact on its reputation, there are situations associated with the establishment of specific plants where locally perceived negative effects could overshadow the value of broad acceptance of the project's green apurpose.

Energinet deems that the opportunities and challenges for Energinet's reputation will be the same or almost the same in both alternatives for the Bornholm Energy Island's electricity infrastructure presented in this business case. However, it is deemed that the alternative where electricity is only transmitted to Zealand may entail a greater risk of negative impact, as this alternative will likely involve more reinforcement of the existing high-voltage grid in Denmark.

Energinet's management of interests and communication rests on trust, openness and dialogue, which are the foundation for Energinet's stakeholder policy.

HOW WE CALCULATED

This section describes the general analytical framework for the business case and the solution alternatives that have been chosen and rejected, and the reasons why.

Framework and assumptions
The framework for preparing the business case for the Bornholm Energy Island's electricity infrastructure is broader than for normal business cases in Energinet. This is because several factors have not been clarified prior to presentation of the business case.

These factors include the capacity of the offshore wind power connected at Bornholm, the development of new technology, collaboration with other players to future-proof the plant for subsequent expansion and connections, and commercial factors.

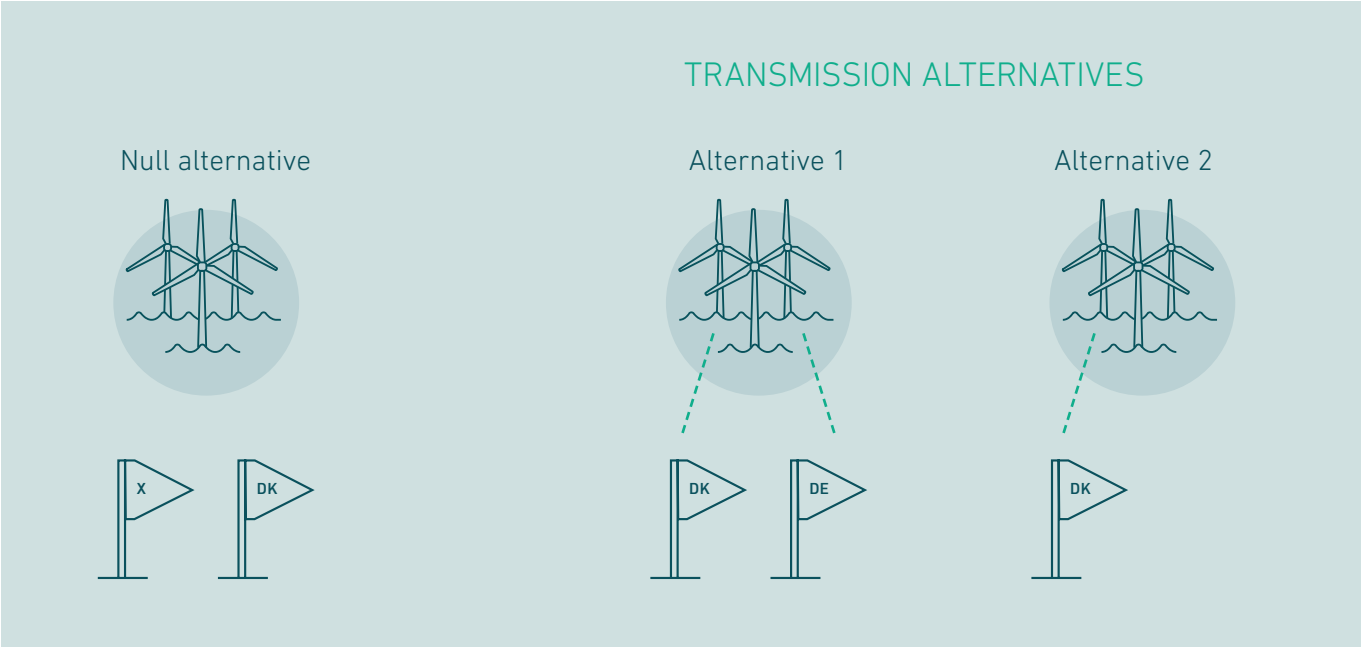
The business case is therefore based on a number of assumptions, leading to significant uncertainties about the results of the analysis. Energinet thus strives to demonstrate in the business case how these assumptions affect risks and costs.

The business case primarily focuses on the consequences of the first stage, while the future perspectives related to connecting more offshore wind power and establishing more international connections are only described briefly and without precise calculations and analyses.

Analysis framework
Energinet is responsible for presenting a business case for establishment of the Bornholm Energy Island's electricity infrastructure and bringing the electricity generated ashore. However, the task is not to present a business case for establishment of the Bornholm Energy Island itself, including wind farms.

As a theoretical null alternative, Energinet therefore assumes in the analysis that offshore wind farms and offshore wind power generation have been established at the Bornholm Energy Island, but no electricity infrastructure has been built to collect and transmit power to the onshore grids. The null alternative normally describes the expected situation if the measures being analysed are not implemented, but in this analysis the null alternative is of a more theoretical nature and not a realistic alternative as such.

BOX 11



The null alternative is compared with alternatives where an electricity infrastructure is established on the energy island and to bring the generated wind power ashore. This is illustrated in the figure on the previous page.

The analysis is designed to answer the following questions: Which electricity transmission facilities are the most cost-effective given that an energy island and associated wind power generation is being established? Using the chosen null alternative, it will be the difference between the economic value of the alternatives that is compared and is relevant to the investment decision. The economic value of each of the two alternatives will seem very high compared to the null alternative. This is because all the economic benefits from the total energy island project and associated wind farms are included for the two alternatives, while the costs of establishing the wind farms have not been included.

The analysis assumes that in all alternatives, plants will be built with a capacity corresponding to at least the offshore wind power generation that is established at Bornholm. No alternatives have been included where the energy is brought ashore in forms such as hydrogen. Since it has been politically decided that Energinet will be responsible for establishing the electricity infrastructure, the analysis has not included alternatives where all or part of the infrastructure is owned by commercial players.

Selected alternatives
Two alternatives have been chosen for connection of the Bornholm Energy Island. Both alternatives assume that plants will be built with a capacity corresponding to at least the offshore wind power generation that is established at Bornholm.

Technical assumptions
The alternatives have been drawn up based on expectations about technological development and future solutions. The alternatives are designed to be flexible in relation to connecting additional offshore wind power or other generation, additional international connections and PtX plants or other innovative projects.

The technical solutions will be designed to allow electrical interconnection on both the AC and DC sides. This adds flexibility and may improve the project economics.

For example, future expansion adding an extra international connection on the DC side will not require new converters on Bornholm, whereas any future expansion of wind power generation will still require extra DC converter stations to be installed.

ALTERNATIVE 1: CONNECTION TO ZEALAND AND GERMANY

Alternative 1 is the solution Energinet recommends in this business case.

Alternative 1 consists of a new substation on Bornholm where the offshore wind farms near Bornholm can be connected to the transmission grid and a new connection from Bornholm to a new substation on Zealand. A 2 GW connection to Germany will also be established in cooperation with German TSO 50Hertz.

A new 400 kV converter station will be established near Solhøj on Zealand. The new substation will be connected to the power grid on Zealand via the existing lines between the Ishøj, Bjæverskov and Hovegård substations.

With a connection point at Solhøj substation, there will be 31 km of underground cables on Zealand, from the coast in Køge Bugt, through several municipalities on Zealand, to a new substation near Solhøj.

One of the advantages of this grid connection point is that it does not require expansion of the existing grid.

The connection from Zealand to the Bornholm Energy Island consists of 209 km of HVDC submarine cables, passing through Danish and Swedish territorial waters. The submarine cables will be bipolar, with a total capacity of 1.2 GW.

On Bornholm, 5 km of HVDC underground cable will be installed from the coast south of Rønne to a new converter station south of Aakirkeby.

The new converter station on Bornholm will be a multi-terminal HVDC solution with AC connection as a backup. Using existing technology, HVDC plant can only be established as point-to-point plant, and no other plant can be connected between the two points. Multiple HVDC plants are connected via alternating current. However, multi-terminal HVDC plant will allow several HVDC plants to be connected on the HVDC side of the plants.

The substation consists of a 1.2 GW converter connected to the cables to Zealand and a 2 GW converter connected to the cables to Germany. The Bornholm substation will also consist of a 400 kV AC installation, which is the connection point for the offshore wind farms.

A 2 GW connection to Germany will be established in cooperation with 50Hertz. This connection consists of 3 km of underground cables on Bornholm and 63 km of submarine cables from Bornholm to the Danish exclusive economic zone (EEZ) border. The submarine cable will then continue for 67 km in German waters and subsequently as an underground cable to a substation in Germany.

ALTERNATIVE 2: CONNECTION TO ZEALAND

Under alternative 2 (DK), a 3 GW connection will be established from the Bornholm Energy Island to Zealand.

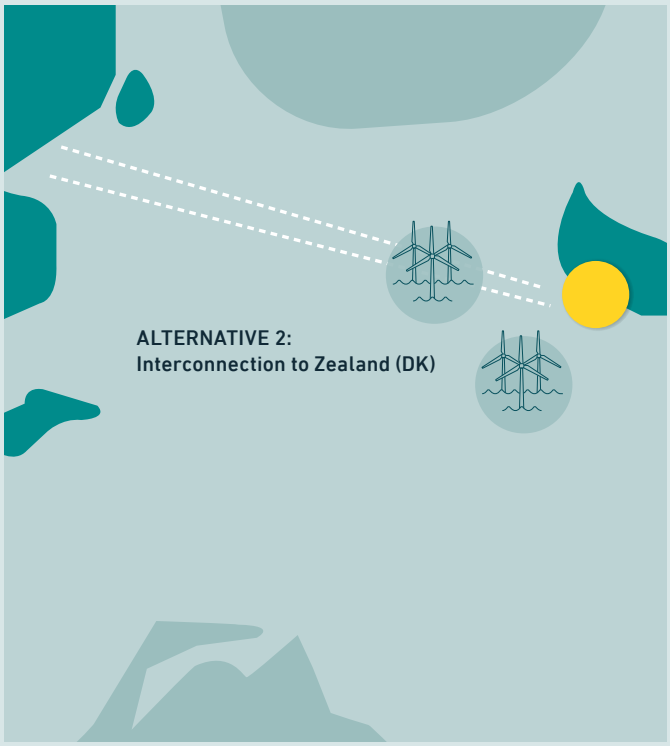
With the chosen null alternative, whereby it is assumed that offshore wind power is connected to Bornholm without the necessary electricity infrastructure, it is the difference between the economic value of the alternatives that is compared and is relevant to the investment decision. This alternative is therefore necessary to show the consequences of an interconnection to Germany. Alternative 2 is thus a methodological alternative and is not deemed to be realistic.

The design basis for this scenario is not at the same level of detail as for alternative 1 (DK + DE), as this scenario is deemed to be expensive, requiring additional costs for internal grid reinforcements on Zealand. This means that greater uncertainty can be expected in relation to the estimated construction budget.

Energinet believes that bringing 3 GW of wind power from the Bornholm Energy Island ashore to the grid on Zealand will require additional grid reinforcement compared to alternative 1 (DK + DE). It is assumed that at least a 400 kV reinforcement between Hovegård and Solhøj will be required. This has been included in the installation budget for alternative 2 (DK).

The substation on Zealand is configured in this scenario to handle the 3 GW of capacity on the cable connection to Zealand and the infeed of 3 GW offshore wind power to Bornholm.

The substation is also designed in this alternative to be flexible towards future connection of additional offshore wind power or international connections.



Locations in the grid on Zealand where electricity can be connected
Energinet has analysed and assessed the most suitable places for connecting electricity from the Bornholm Energy Island to the Zealand grid. The assessment has been based on a number of considerations (environmental, technical, economic etc.), and particularly with the aim of minimising the need to reinforce the existing power grid.

The overall assessment is that a new substation near Solhøj on Zealand, where two high-voltage lines form a Y intersection, is the most suitable location on Zealand to connect power from the Bornholm Energy Island. The analysis therefore assumes in both alternatives that power from the Bornholm Energy Island will be connected to the Zealand electricity grid via a new substation near Solhøj.

However, the connection point will not be finally clarified until Q1 2024, when the authorities are expected to grant relevant final approval under the Danish Environmental Assessment Act.

As part of an environmental assessment of the overall government plan for the Bornholm Energy Island, placing a new substation near Hovegård or Avedøre has been mentioned as potential alternatives. In both cases, Energinet deems that expansion of the existing power grid on Zealand would be necessary.

Connection to the power grid on Bornholm
Energinet's initial analyses show that it will probably be technically possible to connect the Bornholm distribution grid to the Bornholm Energy Island without compromising stability or security of supply.

The business case assumes that the Bornholm Energy Island will be prepared for connection to the power grid on Bornholm, while expansion of the power grid on Bornholm must be handled in a separate business case. In the unlikely event that it is not possible to connect to the power grid on Bornholm, this is not expected to have any significant impacts on the project or the results of this business case.

Offshore wind turbine owners responsible for connection
Both alternatives assume that the owners of the offshore wind turbines will be responsible for connecting power from the turbines to Energinet's high-voltage substation on Bornholm – following the same model as in the tender for the Thor offshore wind farm.

If, during the tender process, it turns out that Energinet must handle the connection, this will mean higher capital costs than assumed in this business case.

Rejected alternatives
The table below describes rejected alternatives and the reasons for rejecting them.

BOX 12

Alternative	Description of solution	Reason for rejection
1 GW connection to Germany	Establishment of a 1 GW connection between the Bornholm Energy Island and Germany	In connection with the TSO collaboration with 50Hertz, both a 1 GW and 2 GW connection between the Bornholm Energy Island and Germany were investigated. 50Hertz is only interested in a 2 GW connection, as it wants to future-proof its investment in relation to any subsequent expansions. The alternative of a 1 GW connection to Germany has therefore been rejected.
AC solution	Establishment of AC cables between Bornholm and Zealand	This alternative has been rejected as it is deemed to not be possible at present to use alternating current on a 209 km submarine cable connection.
Minimal cost solution without the possibility of expansion and using new technology	Establishment of plant to bring 3 GW of offshore wind power ashore, without the option to install more offshore wind power or more international connections in the future	This alternative does not meet the energy island requirement from the political agreements, as it would not be possible to expand and connect more offshore wind power or international connections in future. 50Hertz is not interested in establishing a connection to the Bornholm Energy Island which is not prepared for expected future offshore standards and does not have sufficient flexibility to connect more offshore wind power or more international connections.

APPENDICES

CONSTRUCTION BUDGET AND DERIVED OPERATING EXPENSES

The construction budget for the recommended alternative 1 is presented in the table below.

The budget has been periodised based on implementation during the 2022-2031 period, with commissioning of the new plant in 2029.

The budgets have been stated in constant 2022 prices and include all expected external and internal costs of establishing the plant.

TABLE 8

Construction budget – 2022 prices	DKK millions
[redacted]	
[redacted]	
[redacted]	
[redacted]	
[redacted]	
[redacted]	
[redacted]	
[redacted]	
Core budget (excl. construction interest)	**12,632**
Construction interest	438
Core budget	**13,070**
Estimated supplement (project manager reserve)	398
Steering target	**13,468**
Risk pool	2,620
Budget uncertainty (steering committee reserve)	762
Construction budget	**16,850**

Main items

Total construction costs are budgeted at DKK 16.85 billion in constant 2022 prices. In current prices, the budget is DKK 18.6 billion. The largest items in the core budget cover construction of converters on Zealand and Bornholm, budgeted at [redacted] Of this amount, the purchase of three HVDC converters accounts for [redacted] The purchase and laying of approx. 30 km of underground cable and 209 km of submarine cables will cost a further [redacted]

Steering target

The steering target for Energinet's part of the Bornholm Energy Island of DKK 13.468 billion indicates the most likely outcome. This is the budget that will be made available and is also the project's steering target, not counting the risk pool and steering committee reserve.

The total reserves (risk costs, project manager reserve and steering committee reserve) equal 30 per cent of the core budget (excluding construction loan interest).

The steering committee reserve and risk pool have been set at DKK 762 million and DKK 2,620 million, respectively, and will be managed by the project steering committee.

TABLE 9

Uncertainty costs	DKK millions	%
Risk costs	2,620	21%
Estimated supplement (project manager reserve)	398	3%
Budget uncertainty (steering committee reserve)	762	6%
Percentage of core budget (excl. construction interest)	**3,780**	**30%**

Uncertainties
The recommended budget is subject to major uncertainties, as no similar full-scale projects have been implemented with similar capacity specifications, especially for the converters and cables.

The budget estimates have therefore been based on a combination of comparable realised prices for converters from the COBRA project and Viking Link, and market dialogue – particularly for the underground cable and submarine cable budgets.

The investments will also extend many years into the future. This means the price estimate will be sensitive to general price trends and the suppliers' production capacity at the time of ordering.

The biggest uncertainties in the project are the budget estimates for the purchase of underground and submarine cables – particularly the purchase and installation of the submarine cable. The budget estimate will be particularly sensitive to general price trends, as well as prices for commodities such as the aluminium and copper used in cable conductors.

The market has also expressed that there is a risk of scarce capacity for the production and delivery of cables, due to many projects that need similar specifications, beyond the general requirement for cables for projects. In addition to the market being potentially overloaded, supply chains are generally under pressure at present, and this is expected to continue for many years. The budget for installing the submarine cables to Zealand and Bornholm will also be highly sensitive to weather conditions and the daily rates for ships at the time. The daily rates for ships vary greatly depending on the number of similar activities happening in the market in the given period.

The budget for construction of the building to house the converters and price estimates for the purchase and installation of the HVDC converters are based on realised prices from Viking Link, adjusted to the given dimensions and installation conditions for the Bornholm Energy Island. Reference prices are not available for the HVDC interconnection used in the recommended alternative. The reference prices have therefore been adjusted based on assumptions about the required dimensions.

The budget estimate is also subject to uncertainties in relation to delays or cost increases due to a potential labour shortage in connection with the construction of three buildings and installation of three converters, which must all be completed, installed and commissioned within the same time frame.

The budget for project management covers all internal hours for general project management, including interdisciplinary project support, and is estimated at [redacted] has also been estimated for insurance for onshore and offshore work during the project construction period. [redacted] of the budget estimate for interdisciplinary project management has been allocated to primary project management, the steering committee, project financial management, project procurement, contract law and management. The remaining budget of [redacted] has been allocated to activities close to the construction sites, and covers health and safety, quality (QHSE) and construction site management.

[redacted] has been allocated for emergency preparedness and security, to reduce the level of occupational injuries and ensure a proactive and strong focus on preventive efforts to minimise and avoid occupational injuries in connection with establishment of the Bornholm Energy Island.

DKK 2.62 billion has been allocated to the risk pool based on the project risk analysis. This pool has been calculated as the P50 value of a three-point estimate (min., most likely and max. risk price), where the risk price is the financial impact multiplied by the probability. The aim of the risk pool is to ensure that the project can remedy any realised risks in the project and mitigate risks.

In addition to the costs of constructing the project, a provision of [redacted] has been added for restoration of the substation areas on Zealand and Bornholm and the submarine and underground cables at the end of their service life.

Monte Carlo simulation of core budget
A Monte Carlo simulation was performed to shed light on the uncertainty related to the construction costs of alternative 1 (DK + DE). The simulation currently only considers uncertainty regarding the budgeting of construction costs. Uncertainties related to delays, environmental approvals etc. have not been included in the simulation.

The figure below shows that the mean value for the simulation indicates a core budget of approx. DKK 13.5 billion, 7 per cent higher than the existing core budget. The highest and lowest outcomes in the simulation were DKK 16.8 and 9.7 billion, respectively, corresponding to budget changes of +33% and -23%.

Derived operating expenses
The recommended alternative 1 has budgeted annual operating expenses of [redacted] The operating expenses cover the costs of operating and maintaining two new substations located at Solhøj (DK2) and on Bornholm, connected via an HVDC cable.

The operating expenses are based on both substations being class 1 AIS substations, which require the highest level of security and access control, as well as greater security of supply requirements.

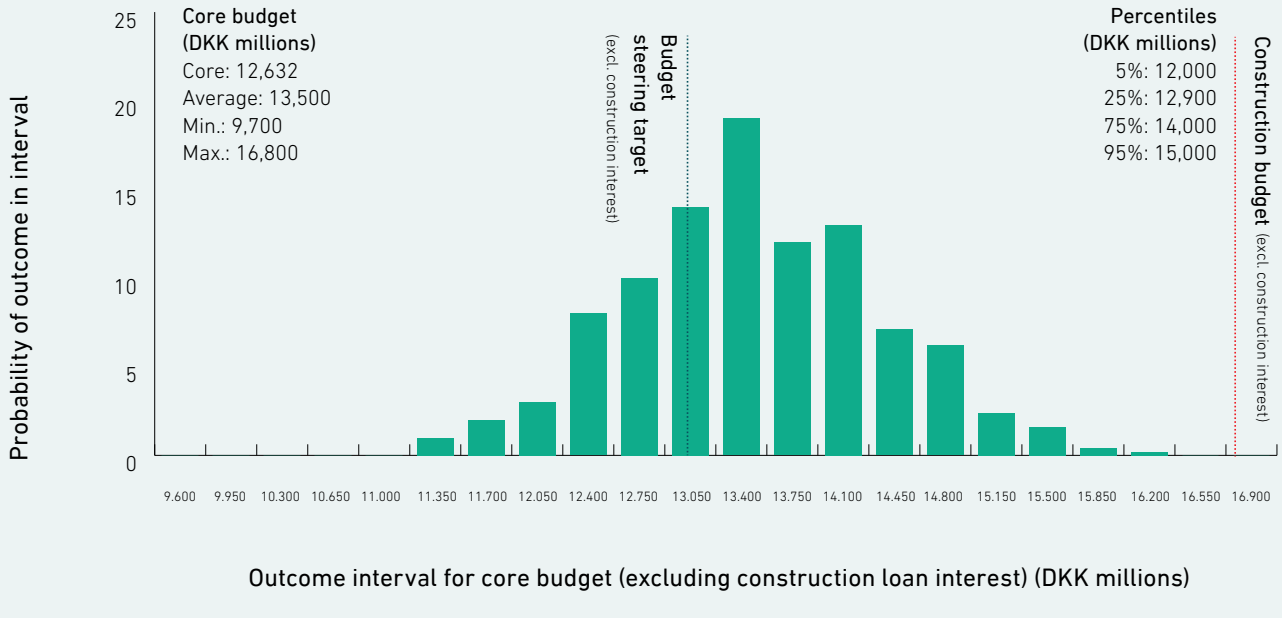
An average annual grid loss of [redacted] is expected for the Bornholm Energy Island.

TABLE 10

Derived operating expenses per year – 2022 prices	DKK millions
[redacted]	[redacted]
[redacted]	[redacted]
Total annual operating expenses	[redacted]

TABLE 11

Core budget outcomes (excluding construction loan interest) based on Monte Carlo simulation



EXPANSION OF THE BORNHOLM ENERGY ISLAND – ECONOMIC PERSPECTIVES

This section presents Energinet's assessment of the economic benefits of possible expansions to the Bornholm Energy Island. Possible expansions here are primarily expansions where the capacity of the electric cables or the offshore wind turbines is increased or where connections are subsequently added to other countries (specifically Sweden and Poland), but the primary alternative is still the recommended alternative 1 (DK + DE).

Greater capacity on the connection to Zealand
The economic costs of increasing the capacity of the electricity connection from the Bornholm Energy Island to Zealand from the assumed 1.2 GW (in the recommendation) to 1.8 GW would be [redacted]

The relatively high increase in costs is primarily due to the need to construct an additional connection (ie a separate cable). The extra, separate connection is necessary because Danish security of supply operates with the 'N-1' criterion – the electricity system must be able to function normally even if a major connection drops out. The size of the dimension-setting unit is 0.6 GW in the Eastern Danish system. A 1.2 GW connection is designed so that a fault can only lead to a maximum outage of 0.6 GW. For a 1.8 GW connection, a fault would result in an outage of 0.9 GW, and security of supply would be compromised. A capacity of 1.8 GW must be therefore be established as a 1.2 GW connection and a 0.6 GW connection.

A 1.2 GW connection between the Bornholm Energy Island and Zealand is also only expected to be fully utilised for 20 per cent of the hours each year when a connection is also established to Germany. The economic benefits of constructing larger connections are therefore limited. If it is deemed to be economically beneficial to establish additional capacity from the Bornholm Energy Island to Zealand at a later stage, alternative 1 (DK + DE) does not limit this option.

Capacity from connected offshore wind power
The political agreement from February 2021 states that 2 GW of offshore wind power must be established at the Bornholm Energy Island. Energinet has been asked to identify, via seabed surveys, an area that can accommodate 3 GW in the preliminary investigations for the Bornholm Energy Island currently underway. However, if 3 GW of offshore wind power is to be installed this will require a new political decision.

The economic benefits are greatest in alternative 1 (DK + DE), regardless of whether 2 or 3 GW of offshore wind power is established. A comparison of the economic benefits shows that the difference in Danish trading gains between alternative 1 (DK + DE) and alternative 2 (DK) will be approx. DKK 2.5 billion less in present value if 2 GW of offshore wind power is established at the Bornholm Energy Island rather than 3 GW. This is because alternative 1 (DK + DE) is able to integrate 3 GW of offshore wind power more efficiently into the electricity system than alternative 2 (DK).

Under alternative 1 (DK + DE), both the connection to Zealand and the connection to Germany will be better utilised if 3 GW of offshore wind power is installed rather than 2 GW. This is because the primary function of the connections from the Bornholm Energy Island is to bring offshore wind power ashore.

Conversely, installation of only 2 GW of offshore wind power will leave more room for electricity trading between the German and the Danish electricity markets, compared to 3 GW. Simulations of the electricity market show that the cable's higher capacity for trading will primarily be used for more trade from Denmark to Germany. At 3 GW, the utilisation for exports from Zealand to Bornholm is 4-5 per cent, while it is 9-10 per cent at 2 GW in both 2030 and 2040.

TABLE 12

Total utilisation percentage in both directions (%/year)	2 GW offshore wind power	3 GW offshore wind power
2030		
Connection from the Bornholm Energy Island to Zealand	35%	43%
Connection from the Bornholm Energy Island to Germany	46%	58%
2040		
Connection from the Bornholm Energy Island to Zealand	43%	51%
Connection from the Bornholm Energy Island to Germany	45%	57%

Congestion rents on the connection to Zealand are virtually unaffected by whether 2 or 3 GW of offshore wind power is installed at Bornholm. However, congestion rents on the connection to Germany will be reduced by 40-45 per cent in both 2030 and 2040 if 2 GW of offshore wind power is installed rather than 3 GW.

Electricity connections to countries other than Germany
Energinet deems it to be of economic interest in both alternatives (DK and DK + DE) to expand the Bornholm Energy Island with additional interconnections to other countries, eg Sweden or Poland.

The net benefit of a new international connection from the Bornholm Energy Island is estimated to be greater in alternative 2 (DK) than alternative 1 (DK + DE). This is because the value of energy from wind turbines at Bornholm can be increased considerably with the first connection directly to another country, but the benefit of subsequent interconnections is less.

The Nordic mix of electricity production, with large proportions of hydroelectric and nuclear power, makes an interconnection between the Bornholm Energy Island and Sweden of interest. This production mix complements both wind power on Bornholm and the central European electricity system well.

Energinet deems the Danish trade benefits from an interconnection to Sweden to be greater in alternative 2 (DK) than alternative 1 (DK + DE). Conversely, Energinet deems the total European trade benefits from adding a connection to Sweden to be greater in alternative 1 (DK + DE) than in alternative 2 (DK).

This indicates that there is more value in connecting Sweden, Germany and Denmark via the Bornholm Energy Island than just Sweden and Denmark. The results for alternative 1 (DK + DE) with Sweden connected also show that congestion around the Bornholm Energy Island will primarily be in the north-south direction between Sweden and Germany, because the exchange between Sweden and Germany yields significant value.

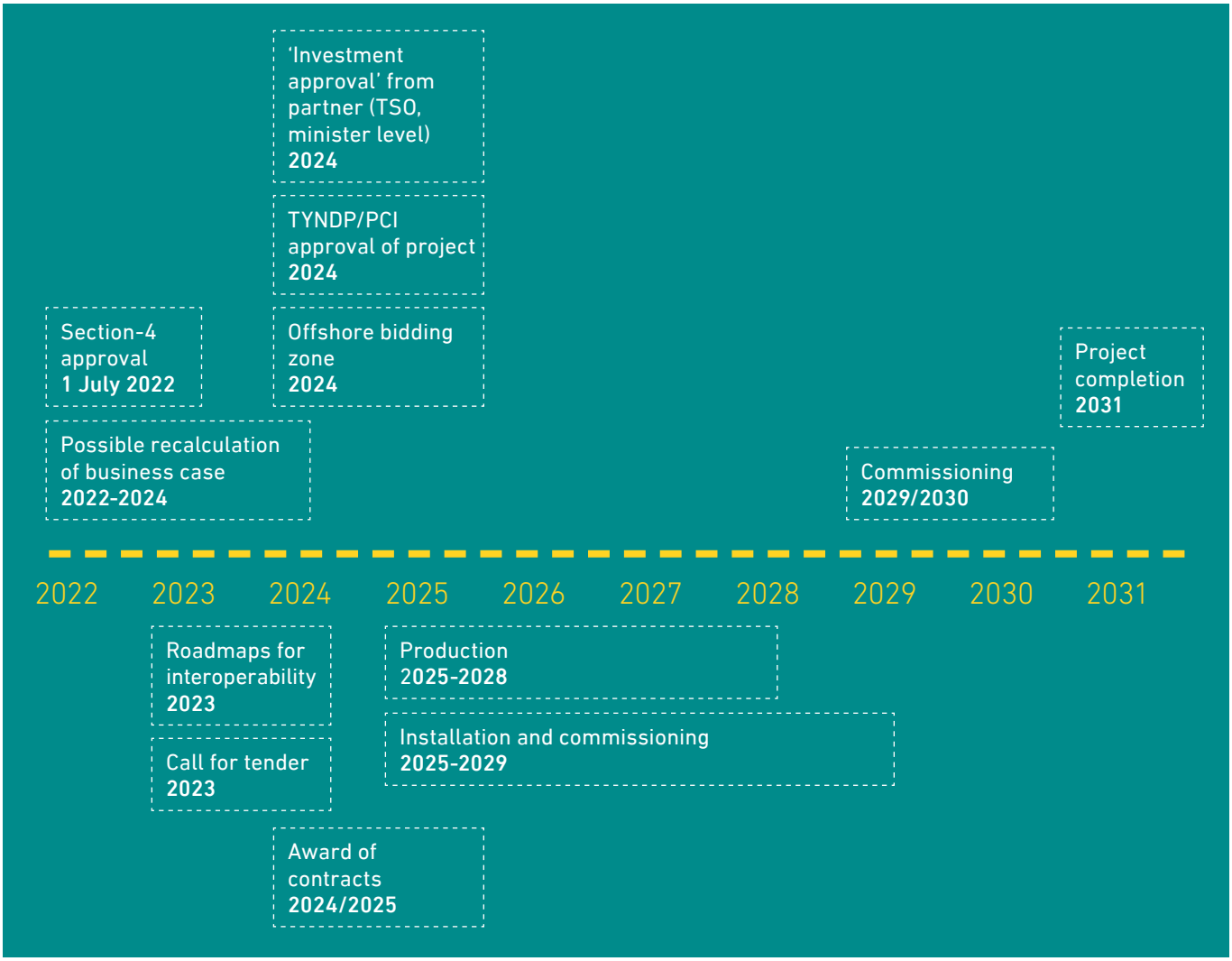
Connection to Poland is of interest due to the expectation of a generally higher electricity price level in Poland. The higher electricity price level is due to expectations of significant growth in electricity consumption, continued generation from coal and gas to a large extent, and a relatively isolated electricity system in Poland.

TIME SCHEDULE

The time schedule will be gradually consolidated with 50Hertz and suppliers through market dialogue, and common functional requirements are being set for the project. During the same period, it must be clarified whether 50Hertz will be part of the first phase of the project or will join later. Following section-4 approval, the project moves to the construction phase, and acquisitions will be made up until the expected award of contracts, where the final time schedule and scope are decided.

Once the large contracts are ready for signature, the business case is expected to be recalculated. From the award of contracts up until presumably 2029, plant will be produced and installed, and the first offshore wind turbines are expected to be connected.

Project completion will only be in 2031 in practice, as Energinet must prepare final documents following commissioning in 2030.



GLOSSARY

50Hertz Transmission GmbH
One of the four TSOs in Germany. 50Hertz is responsible for the electricity grid in eastern Germany.

Alternating Current (AC)
Electrical power which frequently switches direction.

Balance in the electricity system
Electricity generation and consumption must always balance in order to maintain the frequency of approx. 50 Hz in the power system.

Balancing platforms
Cooperation platforms for the exchange of reserves between TSOs across national borders.

Base analysis
The central analysis, based on the best estimate of the future and the consequences of the alternatives examined. The starting point for sensitivity analyses.

Bidding zone
The largest geographical area in which market players can trade electricity without limitations due to internal congestion.

Business case
A description of the reasons for a project and the justification for initiating it, based on a cost-benefit analysis.

Climate year
Various climate years are used to simulate a given future year under different historical weather conditions.

CO_2 emission allowance prices
Market price for carbon emissions.

COBRAcable
Interconnection between the Netherlands and Denmark with a capacity of 700 MW. The connection was commissioned in 2019.

Congestion rents
Profit from the sale of electricity from a bidding zone with a low price in a price area with higher price.

Connecting Europe Facility (CEF)
An EU financing programme for infrastructure investments across the EU in transport, energy and digital projects.

Converter station
Plant where direct current can be converted to alternating current and vice versa.

Cost transfer
To transfer a financial burden to someone or something. It has been politically decided that Energinet's net transmission costs should be transferred to the offshore wind turbine owners, as far as possible.

Direct Current (DC)
Electric current that always runs in the same direction.

DK2
The Eastern Denmark electricity price zone, which includes Zealand, Lolland, Falster, Bornholm etc.

Economics
Economic analysis of the advantages and disadvantages to society of a given investment project.

Electricity infrastructure
All the components that enable the generation, transmission and distribution of electricity.

Electricity market
Market for the purchase and sale of electricity. Consists of a wholesale market and a retail market.

Emergency start-up
Energinet pays players so as to be able to restart the power system from a dead grid in the event of a blackout. Also referred to as black start.

Environmental Impact Assessment (EIA)
Impact assessment which must be carried out before construction projects can be granted permission.

Exclusive Economic Zone (EEZ)
Delimitation of offshore areas where a coastal state has the exclusive right to use the natural resources in the sea, the seabed and underground.

Fast Frequency Reserve (FRR)
Used to ensure frequency stability in situations with low inertia in the electricity system. The reserve is activated automatically at frequency dips below 49.7/49.6/49.5 Hz, and remains active until FCR-D has been fully activated.

Frequency Containment Reserve – Normal operation (FCR-N)
Also known as primary reserve. Used for frequency stabilisation within the normal operation range of 49.9-50.1 Hz.

Frequency Containment Reserve for Disturbances (FCR-D)
Also known as primary reserve. Used to stabilise the frequency in the emergency operation range below 49.9 Hz.

Frequency Restoration Reserve (aFRR)
Also known as secondary reserve. Used for frequency restoration.

Generation adequacy
The probability that enough electricity is available for consumers on demand.

Global Ambition
Scenario in which Europe continues to use global trade to develop and decarbonise the energy system. The scenario was developed by European electricity and gas TSOs for use in TYNDP 2022.

Grid loss
Electricity lost during transport from A to B through lines, cables and substations.

High Voltage Direct Current (HVDC)
A transmission system that uses direct current for the transmission of electricity. HVDC is used in cases where two non-synchronised AC systems have to be connected, or over long underground or submarine cable connections.

Hybrid electrical connection
An electricity connection used to bring power ashore from offshore wind turbines, as well as to connect the electricity markets of two countries.

Kriegers Flak
A 400 MW interconnection between Germany and Denmark via the Kriegers Flak, Baltic 1 and Baltic 2 offshore wind farms. The connection was commissioned in 2020.

Load shedding
The last tool used to protect the electricity system from a blackout. Load shedding is done by completely or partially disconnecting demand at distribution level.

Manual Frequency Restoration Reserves (mFRR)
Also known as tertiary reserve. Used for balance equalisation. The term covers the capacity players make available by agreement with Energinet.

Monte Carlo simulation
Simulation method used to shed light on possible outcomes of an unpredictable event or uncertain variable.

N-1
This principle is used for planning and operating the electricity system. It states that the general functions of the electricity transmission grid must remain intact in the event of an outage on any component in the power system.

Net tax factor
Used to convert factor prices (prices excluding indirect taxes, taxes and subsidies) to market prices.

North Sea Wind Power Hub
International development partnership between the Energinet, TenneT and Gasunie TSOs.

Null alternative
Describes the expected situation without implementation of the analysed measure.

Outage time
A period during which part of the electricity grid is not in operation due to breakdown or maintenance.

Power-to-X (PtX)
Green electricity (power) is converted into something else (x). For example, electricity can be converted into hydrogen via electrolysis.

Project of Common Interest (PCI)
A category of projects the European Commission has identified as key priorities for interconnection of the EU's energy system infrastructure. These projects are entitled to receive government funding, including from the CEF fund.

Properties required to maintain power system stability
The services necessary to maintain secure and stable operation of the electricity system: frequency stability and voltage stability.

Reserves
Purchased electricity capacity made available by players in the event of outage of the largest production unit or exchange capacity. General term for the ancillary services in the form of energy activation and capacity that Energinet purchases to maintain the secure and stable operation of the power system.

GLOSSARY

Ten-Year Network Development Plan (TYNDP)
Every two years, the associations for European electricity and gas system operators (ENTSO-E and ENTSOG) prepare an EU-wide 10-year gas and electricity grid development plan.

Transit compensation
Compensation for grid losses in the electricity grid in a given country caused by increased transit of electricity between neighbouring countries.

Transmission grid
The general supply grid for electricity, natural gas or district heating, which can transmit large energy volumes over long distances.

Transmission System Operator (TSO)
Player who operates and owns the electricity and/or gas grid.

Viking Link
Future interconnection between Great Britain and Denmark with a capacity of 1.4 GW. Planned commissioning in 2023.

APPLICABLE LAW AND POLITICAL DECISIONS REGARDING THE BORNHOLM ENERGY ISLAND

Climate agreement for energy and industry etc. 2020
Date: 22 June 2020

Climate agreement for energy and industry etc. 2020 (fm.dk)

Addendum to the climate agreement on energy and industry of 22 June 2020, regarding the ownership and construction of energy islands etc.
Date: 4 February 2021

Aftaletekst - Energiøer - Ejerskab og konstruktion af energiøer mv.pdf (kefm.dk)

Tender preparation sub-agreement on the long-term framework for tendering and ownership of the North Sea energy island
Date: 1 September 2021

Udbudsforberedende delaftale om langsigtede rammer - energiø Nordsø.pdf (kefm.dk)

Stakeholder policy (Energinet)
Date: 20 November 2018

Energinet's stakeholder policy (Energinet.dk)

Danish Act on Energinet
Act date: 6 February 2020

Danish Consolidated Act on Energinet (retsinformation.dk)

New financial regulation of Energinet
Act date: 12 December 2020

Danish Act amending the Act on Energinet, Danish Electricity Supply Act and Danish Natural Gas Supply Act (retsinformation.dk)

Danish Electricity Supply Act
Act date: 12 May 2021

Danish Electricity Supply Act (retsinformation.dk)

ENERGINET

www.en.energinet.dk/Infrastructure-Projects/Energy-Islands