2023 | ENERGINET

ANNUAL MAGAZINE

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Energinet's annual magazine 2023 provides an easy-to-read update on Energinet's activities, and the opportunities and challenges the company is facing.

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On 8 September 2022, Dan Jørgensen, Minister for Climate, Energy and Utilities, Simon Kollerup, Minister for Industry, Business and Financial Affairs, Jeppe Bruus, Minister for Taxation, and Kristoffer Böttzauw, Director General of the Danish Energy Agency, held a press briefing on the supply situation.
Photo Liselotte Sabroe / Ritzau Scanpix

ENERGY CRISIS
IT'S NOT OVER YET

The energy crisis had taken hold in Europe before Russia invaded Ukraine in February 2022, adding uncertainty and supply fears to the already high energy prices.

The situation was called a 'perfect storm': low stocks in gas storage facilities, followed by war and major cutbacks in Russian gas imports. Added to this were low levels in the Nordic water reservoirs, multiple French nuclear power plants offline for maintenance, a warm summer in Europe (leading to high energy consumption for cooling), drought and low water levels in rivers, leading to a lack of cooling water for power stations and difficulties transporting fuel.

At the beginning of the 2022-2023 autumn and winter season, there was a real risk that Denmark might experience gas or electricity shortages during brief, critical periods. For the first time ever, the government authorities and Energinet might have had to ration gas consumption or electricity supply – either because critical situations had arisen in Denmark, or because neighbouring countries had been affected, thus impacting Denmark. Several neighbouring countries reported specific concerns that power cuts might be necessary over the winter.

But the need for abrupt restrictions to supply did not eventuate, either in Denmark or around us. This was due to many factors – a generally mild winter, extensive wind and rain, major energy savings and efforts to replace the lost Russian gas with alternative supplies (eg through LNG shipped to Europe and increased biogas production), as we have seen in Denmark.

But while there has been a collective sigh of relief in many places, we must be ready for the possibility of further anxiety next winter. And we will need to keep our belt tight. Martin Hansen, Deputy Director General of the Danish Energy Agency, explains.

"We must continue to save energy, so we can begin next winter with lots of gas in the storage facilities. We are pleased that we have exited winter with more gas in the Danish and European gas storage facilities than normal, in part due to Energinet's good work. We are now entering a summer period, during which we need to replenish the storage facilities. Imports of Russian gas to Europe have dropped markedly, so there is a risk that we will be unable to sufficiently refill the European gas storage facilities over the summer and autumn – especially if we do not keep up our thrifty behaviour," he says.

FOUR THINGS
SAVED SUPPLY

WE TOOK ACTION EVERYWHERE
Politicians and authorities in Denmark and the EU protected supply in many areas through initiatives such as filling requirements for gas storage facilities and replacing Russian pipeline gas around Europe with liquid gas (LNG), shipped from the USA, Middle East, etc. In Denmark, temperatures were reduced in government buildings to save energy, and the closure of three power stations was postponed.

WE MOVED CONSUMPTION
Out of fear of supply failures and high energy prices, several large gas-consuming companies switched from gas to other fuels. Danish electricity consumers also began to extensively check electricity prices, and move consumption to the cheaper hours (often hours with high production from wind and solar power). This reduced the need for electricity generated using coal and natural gas.

WE SAVED ENERGY
Danish gas consumption dropped markedly in 2022, by 23 per cent. This is due not only to milder weather, but also lower consumption: Heating (-24%), trade and industry (-19%), households and small businesses (-15%). Electricity consumption, which was otherwise expected to rise, also fell, especially in households (-9%). Even countries which are more dependent on gas managed to save energy and secure alternative supplies.

... AND WE WERE LUCKY
The 2022-2023 winter was wet rather than cold. We used less energy for heating, and the European water reservoirs – which were at very low levels – were refilled. In Denmark, the winter was also very windy, with high green electricity generation. The Baltic Pipe gas pipeline beginning operation in early winter 2022-2023 improved supply in Poland and Eastern Europe, and also in Denmark.

Martin Hansen also notes that the coming winter may prove to be colder and less windy, putting the electricity supply under further strain.

Klaus Winther, Vice President of Energinet, with responsibility for the control centres for electricity and gas, agrees. He reports that we are better prepared in some areas: such as having well-filled gas storage facilities, and the closure of three power stations postponed.

"We are in a more solid position, but there is still uncertainty: how much water will there be in the Nordic hydroelectric power stations? how windy will it be? and how long and cold will the winter be? We are sailing closer to the wind in our energy systems in Europe. We therefore continue to watch the electricity and gas supply closely," he says.

ENERGY APPS ARE CHANGING OUR BEHAVIOUR
Energy price apps have become something we check as often as the weather. 'Min Strøm' (My Electricity) is a good example. It began as a leisure project in March 2022. After less than a year, it has 800,000 users and the effect of the app can be seen in total electricity consumption. All data is retrieved from Energinet. Data supplied in this way (via the 'API') increased by 600% in 2022.

WHAT IF?

We have taken the ready supply of electricity and gas for granted for many years, for good reason. Denmark has had exceptionally high security of supply for decades, and Energinet has never had to make use of controlled customer outages. But after Russia went to war with Ukraine and a major drop in Russian gas imports to the EU, Danes have become more aware of terms like 'brown out' and 'non-protected customers'.

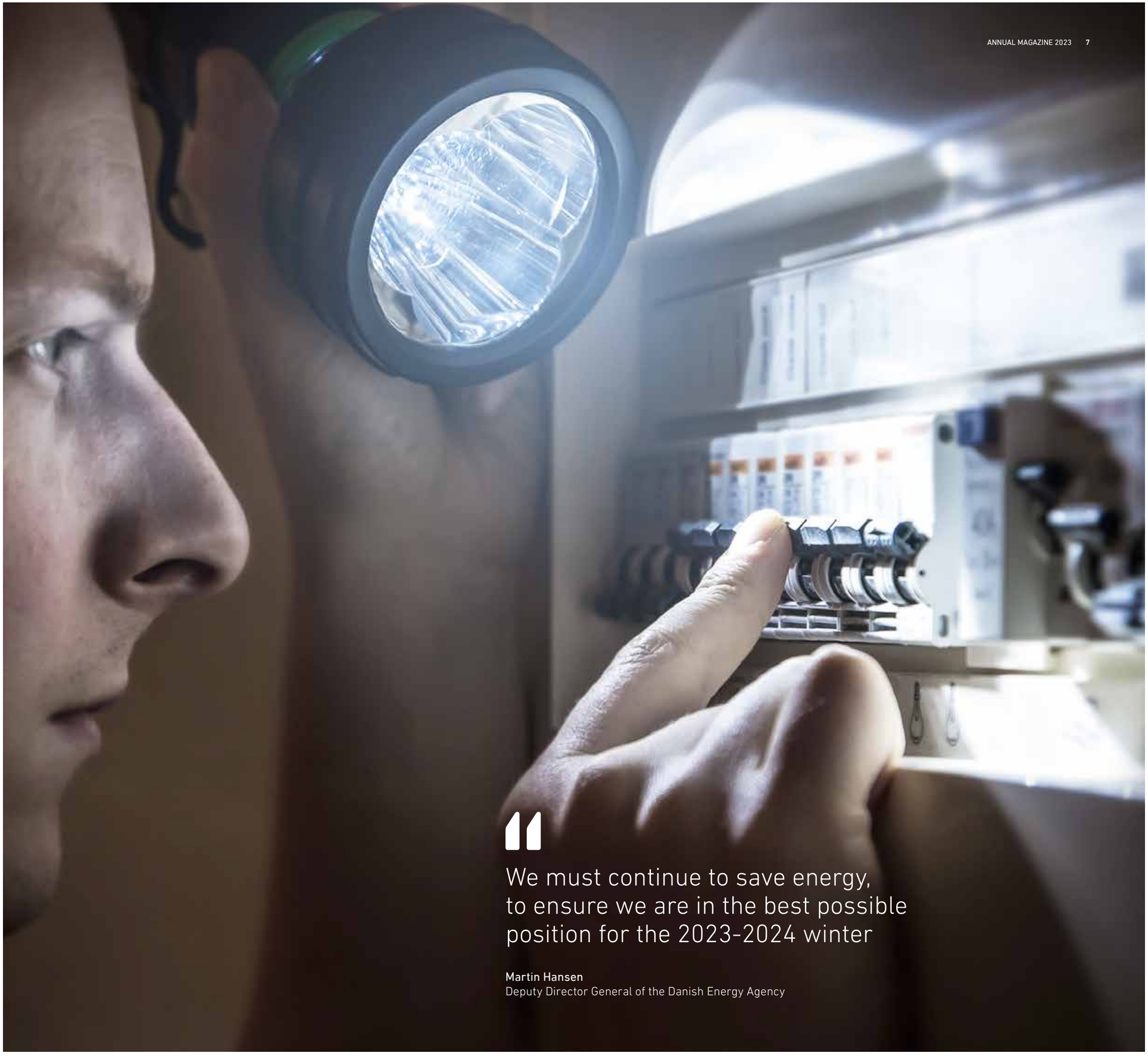
Energinet has always had the option to order some consumption shut down in the event of serious faults in the electricity or gas transmission systems. For example, if a large gas pipeline is cut during excavation or a hurricane blows down high-voltage pylons. But it has never been necessary to use this before.

Due to the energy crisis in Europe, the risk of a supply crisis arising even due to 'non-acute' situations has increased. It is not an excavator or a storm, but rather a supply crisis that we can see looming large. Situations in which the authorities finally have to act and disconnect parts of supply.

The probability is small, but the consequences can be large.

And what if this happens?

You can read more about this on the next page.



> We must continue to save energy, to ensure we are in the best possible position for the 2023-2024 winter

Martin Hansen
Deputy Director General of the Danish Energy Agency

What can trigger a supply crisis in the short or long term – and what will the Danish Energy Agency and Energinet do if this happens?

4 PHASES LEADING TO A SUPPLY CRISIS

ELECTRICITY	SITUATION	ACTION TAKEN
1 YEAR	General energy crisis with high prices and awareness of possible supply problems.	The Danish Energy Agency regularly briefs Danes on the current supply situation and urges them to save energy.
1 WEEK	If very cold and windless weather is forecast for the coming days, and there is a risk of insufficient electricity generation.	The Danish Energy Agency and Energinet will inform Danes of the higher risk of controlled power outages. Danes will be urged to save energy.
1 DAY	If the electricity producers' daily reports to the electricity exchanges show that there is not enough power to meet expected consumption during some hours of the following day.	Energinet and the Danish Energy Agency will inform the public 24 hours beforehand of the specific risk of controlled power outages, and encourage everyone to save electricity during the critical hours to avoid outages.
1 HOUR	If players in the electricity market fail to procure more generation or reduce electricity consumption, Energinet will ultimately take over responsibility for ensuring balance between generation and consumption.	Energinet will use all available reserves to secure supply. If that is not enough, electricity grid companies will be ordered to disconnect supply to, say, 10 or 20% of consumers.

GAS	SITUATION	ACTION TAKEN
1 YEAR	Europe lost much of its former gas supply when Russian gas imports were halted. Focus on filling gas storage facilities, energy savings and converting gas consumption to other forms of energy.	The Danish Energy Agency regularly reports on the supply situation, and urges users to save gas, for example by lowering temperatures in government buildings.
1 WEEK	If the gas supply looks set to become critical in Denmark or its neighbouring countries. For example, if stocks in gas storage facilities get low, or during a period of cold weather, where gas consumption exceeds production, imports and the drawdown on gas storage facilities combined.	The Danish Energy Agency will brief Danes on the strain on the gas supply, and possibly move from 'Normal' to 'Early Warning', 'Alert' or 'Emergency' in the four-step scale in the pan-European crisis system.
1 DAY	A crisis occurs. An 'Emergency' is declared, either by the Danish Energy Agency due to insufficient supply to Danish consumers, or by the European Commission due to a regional crisis covering several countries.	The Danish Energy Agency and Energinet widely inform the public. An emergency does not automatically halt gas to 'non-protected consumers'. If all or part of the list is activated, the affected companies will be notified directly.
1 HOUR	Non-protected consumers can lose their supply no earlier than 72 hours after an 'Emergency' has been declared and a decision has been made to shut down some gas consumption.	Energinet asks Evida, the gas distribution company, to inform the affected companies and shut down their gas, to ensure gas is available for heating private homes and to small consumers, district heating, hospitals etc.

HOW A CONTROLLED POWER OUTAGE IS EFFECTED

1. Energinet contacts the local electricity grid companies, informing them of the percentage of their electricity consumption they have to cut in order to avoid an imbalance between electricity generation and consumption.

2. The grid companies decide which electricity consumers to disconnect from the grid in their area. All grid companies have plans ready for this eventuality. The grid companies solely decide which areas will lose supply.

3. Consumers will be left without power for a maximum of two hours. If the power failure lasts longer, they will be reconnected to the grid, and the local grid company will disconnect other consumers, so that no one loses their electricity for more than two hours at a time. This principle is called a rolling brown out.

4. The rolling brown out will continue until electricity generation can again meet electricity consumption.

HOW A CONTROLLED DISCONNECTION OF GAS CONSUMERS IS EFFECTED

1. If the Danish Energy Agency or the European Commission declares an 'Emergency' in the gas system, it may be necessary to cut some consumption. Energinet prepares a list of 'non-protected gas consumers' each year. These are typically the largest gas-consuming companies, which can be disconnected in the event of a crisis. The authorities may request that all entities on the list, or parts of the list, be cut off from supply, distinguishing between gas consumption critical to society.

2. Energinet asks Evida, the gas distribution company, (and town gas companies) to contact the affected companies.

3. 72 hours after an 'emergency' has been declared, affected companies must stop their gas consumption.

4. A non-protected gas consumer can be disconnected, fully or partially, until the supply situation has improved.

BALTIC PIPE – FROM START TO FINISH

DANISH PART OF THE PROJECT

210 kilometres of gas pipeline have been laid across Denmark.

550 landowners (approx.) in 13 municipalities have been involved in cooperation with Energinet.

5.8 kilometres of pipe can be laid on the seabed each day by the world's largest installation vessel, Pioneering Spirit. The ship is 450 metres long and 130 metres wide.

105 kilometres of gas pipeline in the North Sea – made up of 8,000 welded pipe segments.

100 centimetres is the maximum diameter of the gas pipe.

110 bar is the level the new compressor station in south-east Zealand raises the gas pressure to, in order for it to flow to Poland.

BALTIC PIPE GAS PIPELINE

- Used primarily to send Norwegian gas to Denmark and Poland
- Can transport up to 10 billion cubic metres of gas per year
- Offers financial gain for Denmark, and strengthens security of supply in Denmark, Poland and several Eastern European countries
- Fulfils Poland's wish to end its dependence on Russian gas
- Allows Poland to transition its energy system away from coal more quickly – to gas and green energy
- GAZ-SYSTEM, the Polish systemoperator, laid Baltic Pipe in the Baltic Sea and in Poland

1990
The idea of a Norwegian-Danish-Polish connection is raised right after the fall of the Berlin wall. Several attempts were made to construct the gas pipeline, and abandoned.

2015
Energinet and Polish GAZ-SYSTEM receive EU funds for preliminary studies.

2018
Energinet and GAZ-SYSTEM make final investment decisions.

2019
Excavators begin digging in Denmark.

2021
Baltic Pipe loses its environmental permit, and part of the construction work is put on hold until 1 March 2022.

2022
Baltic Pipe is officially opened on 27 September with much media attention. In addition to attendance by the prime ministers of both countries, the opening comes the day after the Russian North Stream gas pipelines in the Baltic Sea are sabotaged.

2022
Baltic Pipe commences operation at full capacity on 30 November.

2023
The project is completed.

David Dupont-Mouritzen
Project Director, Høst PtX Esbjerg
Photo Copenhagen Infrastructure Partners (CIP)

Power-to-X converts renewable energy into hydrogen and other climate-friendly fuels. This is done using electrolysis – a process whereby water is split into hydrogen and oxygen using green electricity.

HYDROGEN
EXPORTS CAN SUPPORT GREEN TRANSITION

It will take a lot of solar cells and wind turbines to meet Denmark's total electricity consumption using green power. Eventually, this will mean that we have more renewable energy than we can use directly at times. Electricity and hydrogen will therefore become close allies, because the green power can be converted into hydrogen, which can be exported.

Denmark is well underway with the green transition. The goal is a future with 100% green electricity flowing in the grid, and if Denmark exploits its great renewable energy potential to reach this goal, we will end up with a lot of wind turbines and solar cells.

"There will be much more green energy than we can use in the electricity system for much of the time each year. It will be expensive to expand the power grid to handle peak production, and it will only be profitable to expand the production of green energy so far beyond our classic needs if we have flexible consumption to make use of it," says Martin Hartvig, senior engineer and hydrogen expert at Energinet.

Electricity + water = hydrogen
Hydrogen production is one of the ways the extra power can be utilised. Through electrolysis, water can be split to form hydrogen and other derived materials. The method is called Power-to-X.

Hydrogen can be used directly as a fuel for transport, or for making products such as green fertilisers or methanol. As Martin Hartvig puts it, this is the "sexy part of Power-to-X".

"However, from a climate perspective, it's more important that we can power our electricity grid with wind and solar energy for much of the time – even when there is only light wind or limited sunshine," notes Martin Hartvig.

"Denmark has almost no direct hydrogen need today. So new Power-to-X consumption will be required, converting hydrogen into ammonia, methanol or the like. We have much more extensive power resources than we need ourselves, so hydrogen exports and Power-to-X products make sense. Also from a climate perspective. We will be able to replace consumption in Europe which is currently being met by fossil energy sources."

Close allies
Electricity and hydrogen can thus become close allies. One of the customers for green power is Copenhagen Infrastructure Partners (CIP), which invests in energy infrastructure with a special focus on green energy. In early 2023, Energinet entered into a grid connection agreement with CIP and others, which connects a Power-to-X plant to Energinet's substation in Endrup near Esbjerg.

With access to electricity from Endrup, CIP will produce green ammonia from hydrogen at its HØST PtX Esbjerg plant. To allow conversion of fluctuating wind and solar power, the factory will be designed with a hydrogen storage facility and ammonia tanks. You could say that a Power-to-X plant actually functions as a large molecular battery for storing green electricity.

David Dupont-Mouritzen, Project Director for HØST PtX Esbjerg, affirms the prediction that electricity and hydrogen could become close allies.

"We're very aware of this. That's why we chose Esbjerg for our plant. There's access to solid electricity infrastructure, and proximity to the North Sea, where we will see great future expansion in offshore wind power. Electricity and hydrogen go hand in hand. Without a flexible large-scale consumer of the electricity generated from offshore wind power, Denmark will be unable to realise the full energy potential in the North Sea. The electrolysis is the primary large-scale power consumer, but this is also the part of a Power-to-X plant that can best be ramped up and down – depending on how much electricity is available," says David Dupont-Mouritzen.

In society's interest

It has also been important to CIP to build something that benefits society. This is one of the investment company's investment principles. And hydrogen plants will be necessary if Denmark is to expand its offshore wind power on a large scale.

"If you believe that the climate challenges are best addressed jointly by the private and public sectors, we have the right set-up here. The alternative is that the government has to build its own Power-to-X plants corresponding to 4-6 GW consumption, as announced in the government's Power-to-X strategy," says David Dupont-Mouritzen.

He notes that CIP is also closely monitoring developments in hydrogen infrastructure.

"It's extremely important that we get hydrogen infrastructure that connects Denmark to Europe. A market will be needed to take up the hydrogen produced using North Sea wind power. If we have the right conditions in place for building Power-to-X plants and an infrastructure to transport hydrogen, we cannot build too many wind farms, or build them too quickly."

The CIP believes there is considerable export potential. Denmark's natural gas production peaked near the turn of the millennium at around 8-10 billion cubic metres per year. If the offshore wind power potential in the North Sea is utilised up to the 35GW calculated, it will correspond to at least one and half times the peak natural gas production.

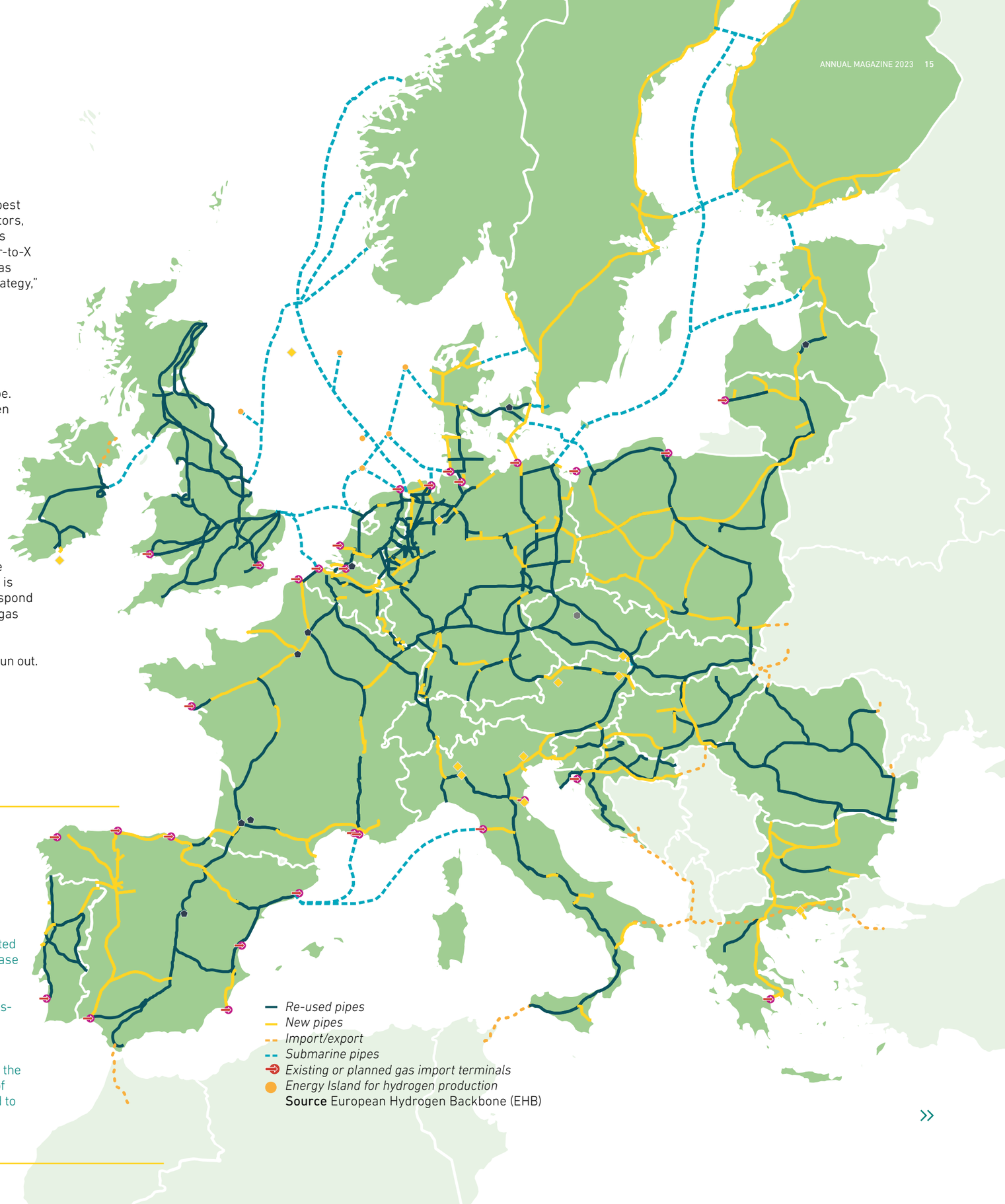
And this is from a source – wind – that does not run out.

HYDROGEN MOTORWAYS COMING SOON

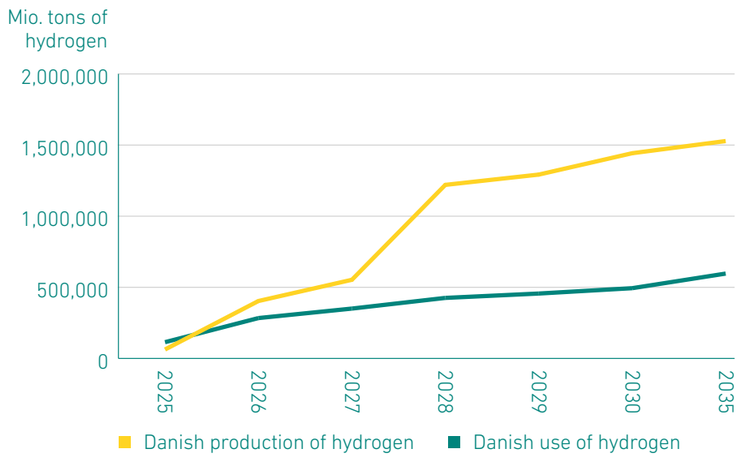
Energinet is currently investigating the basis for establishing Danish hydrogen infrastructure, to be connected from Jutland to the future German hydrogen grid. Preliminary analyses show an excellent cost-benefit case for the hydrogen grid. The analyses also cover a hydrogen storage facility in Jutland.

Energinet has already begun working with Gasunie Deutschland on the possibilities for establishing cross-border infrastructure for hydrogen. The two operators have signed an agreement on behalf of the future Danish and German hydrogen grid operators, as it has not yet been decided who these will be.

At European level, Energinet and 30 other energy infrastructure operators from 28 countries are looking at the possibility of building a 'European Hydrogen Backbone'. The initiative could encompass 53,000 kilometres of hydrogen pipes in Europe by 2040. Over 60 per cent will be based on existing gas pipelines being converted to hydrogen.



Source European Hydrogen Backbone (EHB)



There are plans for large-scale hydrogen production in Denmark. Denmark cannot use the hydrogen itself, and the surplus hydrogen can be exported.
Source Market dialogue conducted in 2022 by KPMG, Evida and Energinet

GERMANY NEEDS **HYDROGEN**

Countries like the Netherlands and Germany are obvious potential export markets. Denmark is a small country with large territorial waters, and the Danish North Sea region is shallow – an ideal place to erect wind turbines. Germany does not have the same opportunities to produce plentiful wind power, but with more than 80 million inhabitants, it has a greater need for hydrogen in industry than we do.

Denmark will be in competition with regions like North Africa. These countries can install very extensive wind and solar cell farms, and thus produce cheap hydrogen. Even cheaper than is possible in Denmark. The disadvantage is that it must be transported thousands of kilometres to markets like Germany. Denmark has the advantage of being close to large German consumption, and transport is therefore cheaper. Production costs will also be kept down if we only convert electricity to hydrogen during the 'cheap hours', when there is abundant electricity.

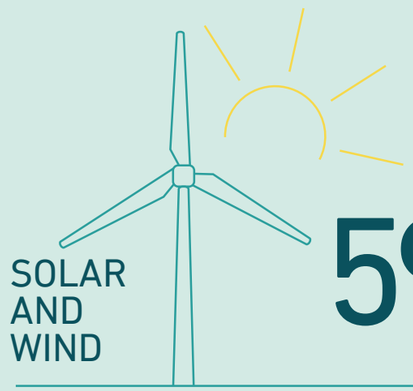
According to calculations in TYNDP22 (Europe's Ten-Year Network Development Plan), Denmark will be able to supply up to 20% of Germany's hydrogen needs through high utilisation of its own resources.

TYNDP is prepared by ENTSO-E and ENTSOG, the European networks for electricity and gas transmission operators.

WE NEED LOTS OF OFFSHORE WIND POWER
Denmark initiated closer energy cooperation with its neighbours in 2022. Denmark, Sweden, Finland, Germany, Poland, Estonia, Latvia and Lithuania have signed the Marienborg declaration, which sets a common goal of a sevenfold increase in offshore wind capacity in the Baltic Sea by 2030.

Denmark has also signed the Esbjerg declaration, jointly with Germany, Belgium and the Netherlands, which aims to make the North Sea a green power centre for all of Europe. The four countries are aiming for at least a tenfold increase in offshore wind power capacity by 2050.

ENERGY FIGURES 2022

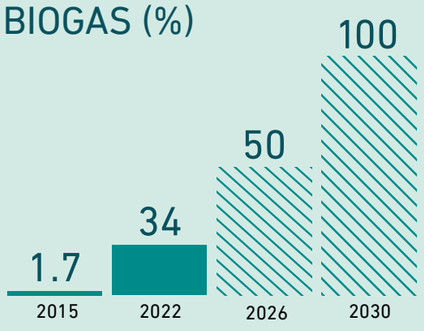


SOLAR AND WIND

59.6%
2015 **40%**

In 2030, 100% of our electricity consumption is expected to be met by solar and wind power.

BIOGAS (%)



HIGH SECURITY OF ELECTRICITY SUPPLY

117 sec.
WITHOUT ELECTRICITY

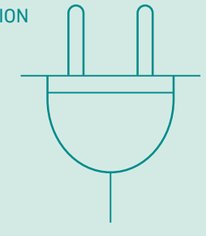
Despite 2022 being out of the ordinary, security of supply was again among the best in the world.

SAME ELECTRICITY PRICE AS ABROAD

MEASURED AS PROPORTION OF HOURS

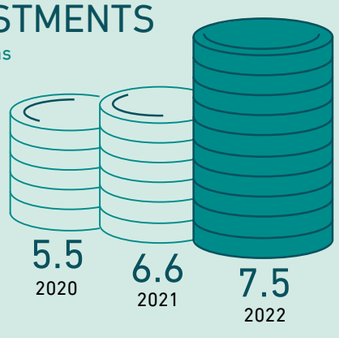
West Denmark
93 %

East Denmark
85 %



FIXED ASSET INVESTMENTS

DKK billions



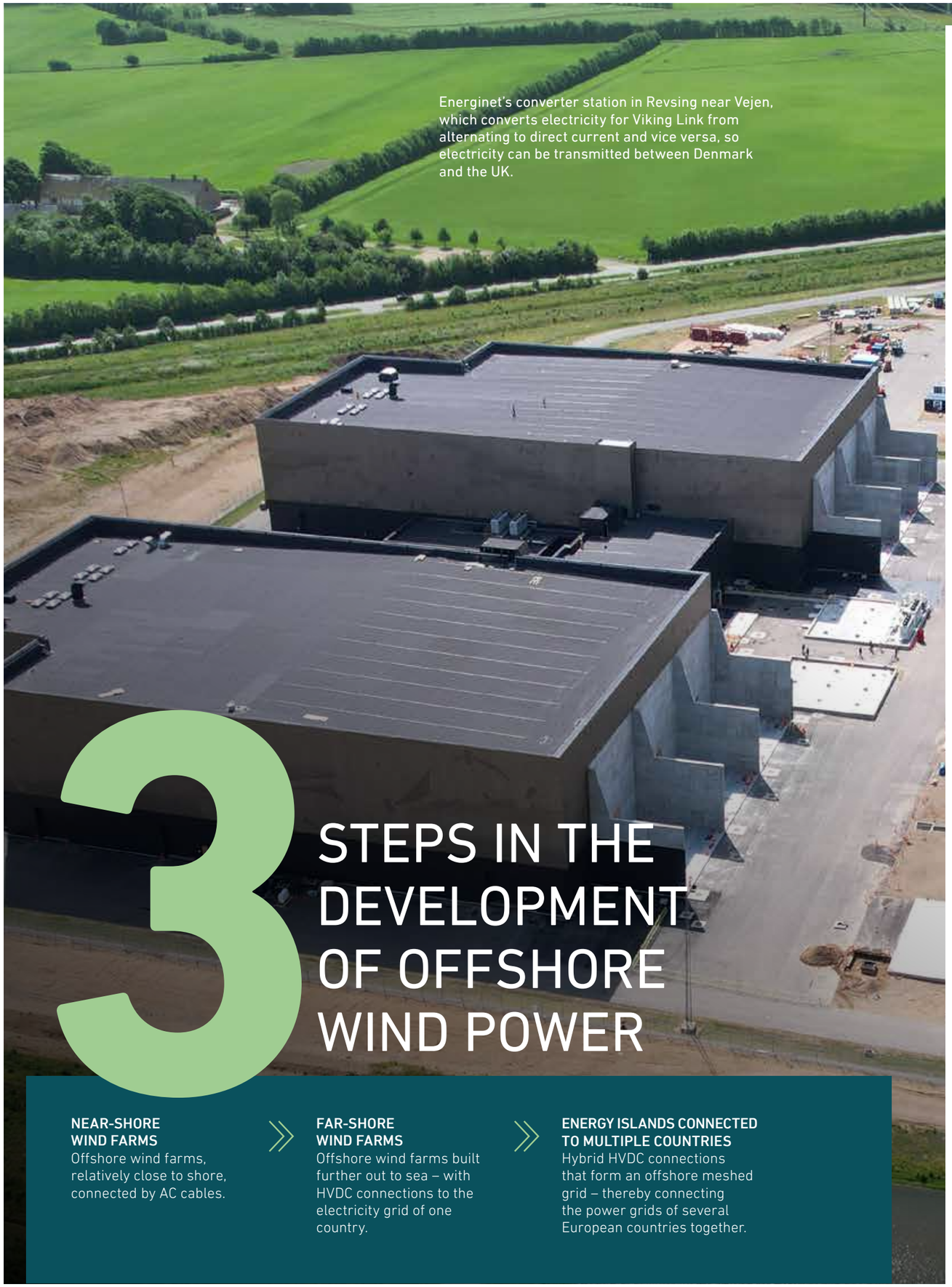
If you stand in a converter plant and look up, you are almost awestruck that people are capable of building such things

Christian Flytkjær
Senior Manager in Energinet's electricity system design department

ENERGY ISLANDS – A HIGH-VOLTAGE TECHNOLOGICAL LEAP

The future energy islands will be enormous constructions in North European waters. But despite the spectacular feat it will be to build artificial islands hundreds of kilometres from shore, this is not the critical innovation factor in relation to energy islands. The critical factor is the offshore power grid between the energy islands. We have taken a snapshot of the high-voltage technological leap that can move Europe into a new era for large-scale offshore wind power.

Photo shows Siemens Energy HVDC PLUS Converter Technology



Energinet's converter station in Revsing near Vejen, which converts electricity for Viking Link from alternating to direct current and vice versa, so electricity can be transmitted between Denmark and the UK.

3 STEPS IN THE DEVELOPMENT OF OFFSHORE WIND POWER

NEAR-SHORE WIND FARMS
Offshore wind farms, relatively close to shore, connected by AC cables.

FAR-SHORE WIND FARMS
Offshore wind farms built further out to sea – with HVDC connections to the electricity grid of one country.

ENERGY ISLANDS CONNECTED TO MULTIPLE COUNTRIES
Hybrid HVDC connections that form an offshore meshed grid – thereby connecting the power grids of several European countries together.

DIRECT CURRENT VERSUS ALTERNATING CURRENT

We have built up a functional and cohesive electricity grid on land over the years, using alternating current. We cannot use the same solution far out to sea, as alternating current cannot be transported efficiently over distances greater than about 80 kilometres. An offshore power grid must therefore be made up of direct current cables. Unfortunately these have their own challenges – they are difficult to decouple, and require highly complicated control systems.

"If you stand in a converter plant and look up, you are almost awestruck that people are capable of building such things." The comment comes from Christian Flytkjær, Senior Manager in Energinet's electricity system design department. In the converter plant where he is standing, alternating current be converted to direct current and vice versa.

Converter plants such as this one will play a central role in the future offshore power grid. Together with DC circuit breakers, they will form part of the electricity grid, and be placed both onshore and on the energy islands.

Meshed offshore power grid
Over the past 70 years or so, we have gradually built up a cohesive electricity grid on land using alternating current. Individual power stations are not directly connected by separate power lines or cables to each town or large factory that needs the power. Instead, both producers and consumers are connected to a cohesive electricity grid by motorways (the transmission grid) and highways (the distribution grid), which transport the electricity from power stations, wind turbines and solar cells to houses, factories, nurseries, hospitals, schools, etc.

The technical term for such an arrangement is a 'meshed grid'. A meshed grid has the great advantage that any fault or outage at a power station or on a line or a cable does not take down the electricity throughout the grid. If one road is closed due to roadwork or an accident, there is always another route the electricity can take – to use a vehicle metaphor. It is such a meshed electricity grid that Energinet must begin building far out in the North Sea and Baltic Sea. Otherwise it will not be possible to distribute the enormous volumes of offshore wind power to households and industries throughout Europe.

"Given that we need to harvest over 300 GW of offshore wind power in European waters by 2050, we cannot continue to build offshore wind farms by connecting them point-to-point, ie with one connection between each wind farm and the onshore electricity grid. We would end up with a spaghetti-like mess of cables on the seabed," says Christian Flytkjær.

Direct current is the key – and the challenge
So the task is to create a power grid at sea that is meshed, and thus flexibly connects production and consumption, just like the power grid on land. But when you connect wind turbines and the power grids of several countries, the power must flow as direct current over very large distances, before connecting to the power grid in a given country using a converter station like the one Christian Flytkjær is visiting in the photo on page 18.

Alternating current cannot be transported efficiently in cables over distances greater than around 80 kilometres. This is because alternating current in cables produces 'reactive power'. Reactive power can be understood as a kind of noise that builds up. The longer the cable, the greater the reduction in the energy that is transmitted and can be used.

Direct current does not produce reactive power in cables, and can therefore be transported over very long distances without significant energy losses. The meshed power grid at sea therefore needs to be made of DC cables, but these present other challenges. Put very simply, the challenges with direct current can be reduced to two things: An offshore DC grid will require highly complicated control systems, and it is far more difficult to decouple direct current at high voltage levels than it is to decouple alternating current.

Difficult to decouple direct current
Let us take the latter first. Alternating current in a 50 Hertz grid changes direction 100 times a second. Each time it changes direction, the current drops to zero amps. At the exact moment it becomes zero, it can be decoupled. Direct current does not change direction. The current therefore never drops to zero amps, making it much harder to decouple.

Christian Flytkjær notes: "The challenge with direct current is that the current never drops to zero, so if you try to cut off the current, an arc or spark will result, and burn at several thousand degrees. We do not have materials that can withstand this, so there is a risk of explosion and hazard to the surroundings and security of supply."

A set of contacts that can decouple direct current at a very high voltage level – a DC circuit breaker – is not currently in operation anywhere in Europe. They are being developed, and some manufacturers are taking orders. But it is immature technology, even though some are in operation in China.

As the offshore DC grid grows larger, DC circuit breakers will become vitally important. Without them, it will not be possible to isolate faults in parts of the grid from the rest of the grid, and the system therefore cannot be operated safely.

The energy islands in Denmark will be an artificial island 100 kilometres off the west coast of Jutland in the North Sea, and Bornholm in the middle of the Baltic Sea. From the early 2030s, these will together collect 6 GW of offshore wind power and connect Denmark with Germany and Belgium via new interconnections. The energy island in the North Sea will later be expanded to at least 10 GW. On Bornholm, Energinet, the Technical University of Denmark, the Municipality of Bornholm and several other parties have joined forces in Baltic Energy Island – an international meeting place for the development of energy islands and green energy.

Maja Felicia Bendtsen is Chief Business Officer at Rønne Harbour, and head of the Bornholm Bunker Hub consortium. Ørsted, Molslinjen, Haldor Topsøe and Bunker Holding are also represented in the consortium.

Jacob Østergaard is a Professor and Head of Division at the Department of Wind and Energy Systems at the Technical University of Denmark (DTU). He heads several research projects looking at energy islands.

What is Bornholm Bunker Hub?
Bornholm Bunker Hub is a vision to exploit the fact we now have sufficient power available to produce some green fuels via electrolysis and Power-to-X. It is very likely that the large catamaran ferries sailing to and from Bornholm will have to use green fuels rather than batteries – as the energy density of batteries is too low for such vessels. The 60,000 ships that pass Bornholm each year will also need to use green fuels in the future. Finally, hydrogen production will be used to balance the electricity system. Bornholm has a very central location in this regard, and could contribute to balancing the Danish, German, Swedish and Polish electricity systems in the long term.

What value can the Bunker Hub vision create for Bornholm?
There are more flow-on opportunities than the ones I have just mentioned. Electrolysis has two residual products – heat and oxygen. I think it's time we started looking beyond the energy sector when we talk about sector coupling. We can of course use surplus heat in district heating, but we can also start doing business development involving heat and oxygen. Creating symbiosis with horticulture, fish farming and biogas plants would be obvious candidates. But there are many possibilities, and Bornholm needs to create new opportunities for earnings and employment.

What do you hope to have contributed from a research perspective when several energy islands and an offshore power grid have been realised?
Given the need to build energy islands and a functioning HVDC grid, there are many technological issues that we need to help develop solutions for. How to control them, how to ensure that a single fault does not result in disconnection of a 10 GW energy island, which could potentially take down the entire European electricity system, and how to integrate hydrogen and Power-to-X. These are some of the issues we will help to address.

What opportunities do you see in the Bornholm Energy Island as a meeting place for energy island development?
Bornholm is highly interesting, as we have a good history of developing energy system solutions on the island in cooperation with citizens, the municipality, the energy sector and the business community. Bornholm is more accessible than the North Sea, and with Baltic Energy Island, I think Bornholm can become a fantastic international meeting place for everyone who wants to work together on the development and testing of the future energy island technology.

Illustration The Danish Energy Agency

Everything must be managed using computers and controllers
There are power stations on land which transmit alternating current into the grid using large rotating generators. If alternating current is unable to pass through a specific line or cable in the grid, it will automatically flow through another line or cable, as long as this has sufficient capacity. This is not the case in a meshed direct current grid. This is the second major challenge.

This is an advanced electrotechnology issue, and Christian Flytkjær tries to put it simply: "While much of the control we need in the AC grid on land gets a helping hand from the laws of physics, a DC grid is much more dependent on control, and thus the controllers that highly skilled people have developed."

One of Europe's largest R&D projects
Denmark has many offshore areas favourable to offshore wind power. So far, we have been able to establish offshore wind farms connected using AC cables, relatively close to the shore. This is the first step in developing offshore wind power.

The next step is to establish offshore wind farms with DC connections further out to sea, but still only connected directly to one country's electricity grid at a time. Several countries already have experience with this step, including Germany and the Netherlands.

The third development step is to create hybrid HVDC connections. These will gradually form a meshed grid at sea, carrying large amounts of offshore wind power to European countries, while also making their power systems even more interconnected than today.

Perhaps the best illustration that this third step is no simple matter is the fact that the research and development project to help achieve it is one of the largest innovation projects ever launched under the EU's Horizon Europe Framework Programme. The project is called InterOPERA, and has been granted DKK 400 million in EU funds. Under the project, Energinet has teamed up with seven other TSOs, suppliers of DC equipment, offshore wind developers and researchers to solve what Christian Flytkjær calls the vicious innovation circle:

"As the client, we cannot place orders for the facilities, because we don't know exactly what we can or need to order. As suppliers, they cannot start developing it until we order it."

InterOPERA began in January 2023, and must deliver its final results in spring 2027. The aim is to describe the technical, regulatory and legal framework necessary to allow the HVDC grid to be gradually built – with converters, circuit breakers and cables – in a way that ensures these components function seamlessly with each other – even though they come from a wide range of suppliers.

ENERGINET IN MAJOR GROWTH

Denmark has to accelerate the green transition in record time and ensure independence from Russian energy. In order for Energinet to handle its part of this key task for society, more employees are needed. Which tasks are we going to carry out, and how will we get hold of all these new employees?

Within the next two years, Energinet will add 500 new employees to its ranks. We will not only be working on major expansions to the electricity and gas grids and contributing to a brand new hydrogen infrastructure. In a few years' time, when the vast majority of our electricity comes from green and renewable energy, and we have plants spread across land and sea, we will need to develop whole new markets, control systems and IT solutions, to ensure a stable and secure energy supply for Danes. We also live in a world in which we increasingly need to protect ourselves against cyber-crime and keep intruders out.

"We are entering a new era, where we need to do much more of what we have done for many years, but also take on tasks we have never done before. This will require new knowledge, new expertise and more hands. Even if we prioritise our tasks very strictly and outsource more activities to external players in future, we cannot avoid a major recruitment drive," notes Stina Willumsen, Vice President, HR, Strategy and Communication.

Diverse workplace with exciting roles

Energinet is generally seeing increasing interest from the outside world, as the energy crisis has drawn a lot of attention to the energy sector. This also applies to the recruitment of new employees, where the prospect of new tasks, a flexible setting and a good working environment need to help attract new blood.

"We are a workplace that offers many exciting tasks, where people have the opportunity to become a part of the green transition. For example, you can help build the world's first energy islands, or develop new IT solutions to support a green energy system. At Energinet, we uphold a working environment where we take good care of new employees and look after each other.

We also seek to support a good work-life balance. We therefore offer a high degree of work flexibility and excellent conditions for parents – such as five days of leave in connection with child illness and the option of a 32-hour working week at full pay for six months after parental leave. Our satisfaction survey also shows that we have a fantastic workplace," says Stina Willumsen.

However, Energinet is also seeing growth across the energy sector – not just in Denmark. We are seeing the same trend throughout Europe. TSOs (transmission system operators) are adding to their staff to ensure a green and stable energy supply for their citizens. So there will be a battle for employees – even across national borders.

"Like the rest of the sector, Energinet needs more young people to enrol in technological and science degree programmes. Otherwise there will be a shortage of staff in the long term. That concerns me a little. I would also like more women to consider our sector. By doing more degree programmes related to technology and energy, but also by taking a chance and applying for a job in the energy sector, even though they may have no experience in it."

"Since we need to develop a new and different energy system, we also need new perspectives on how to address the challenges. We therefore have a goal of increasing diversity in Energinet, and bringing a variety of disciplines and life experience together. Companies simply develop best when diverse people work together."

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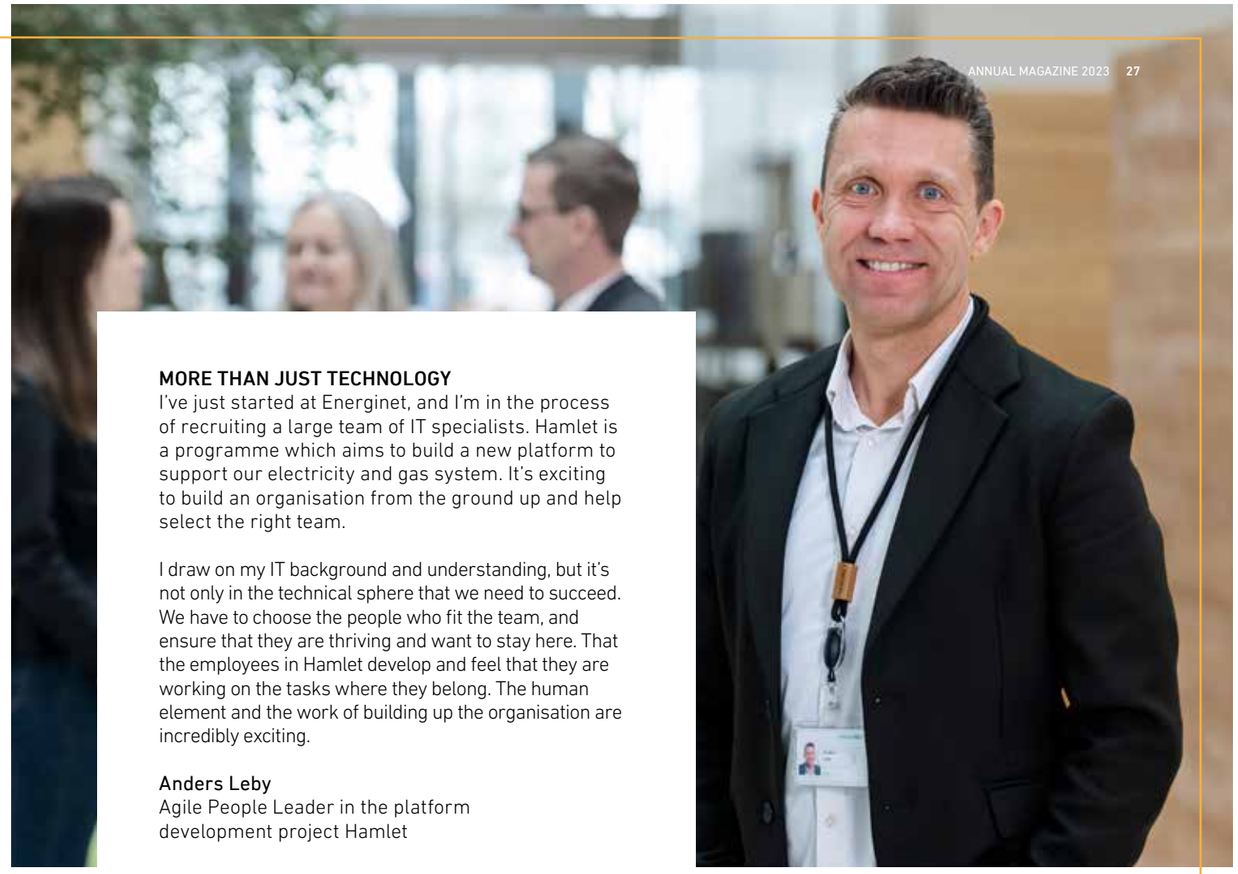
ENERGINET HAS TO HANDLE 400% MORE GREEN ENERGY IN JUST EIGHT YEARS

Energinet will need new and more expertise. People who will work on connecting more green energy, expanding and replacing existing energy systems, developing energy islands, a new IT system for controlling and securing the energy system, and a range of support functions such as purchasers, lawyers, economists, HR employees, etc. Energinet currently has 1,800 employees, and expects to have approx. 2,300 at the end of 2024.

THE COOLEST PROJECT IN THE WORLD
Working with energy islands is complex and extremely interesting. We have to build something that has never been built before, and we have to find the solutions ourselves. It's not easy, but I want to help make the world a greener place. My job is to ensure the project is as sustainable and safe as possible, and I'm very dependent on the professional knowledge across the organisation. I am new at Energinet, and have worked hard to build the relationships that can help me.

While we have a flexible workplace, I like to be here physically. It makes networking easier. We need to do things together if we are to succeed, and there are many new people. Energinet is growing and growing. This is a challenge, but also exciting.

Signe Marie Sundekilde
Project Manager for Sustainability and Safety
– Bornholm Energy Island



MORE THAN JUST TECHNOLOGY
I've just started at Energinet, and I'm in the process of recruiting a large team of IT specialists. Hamlet is a programme which aims to build a new platform to support our electricity and gas system. It's exciting to build an organisation from the ground up and help select the right team.

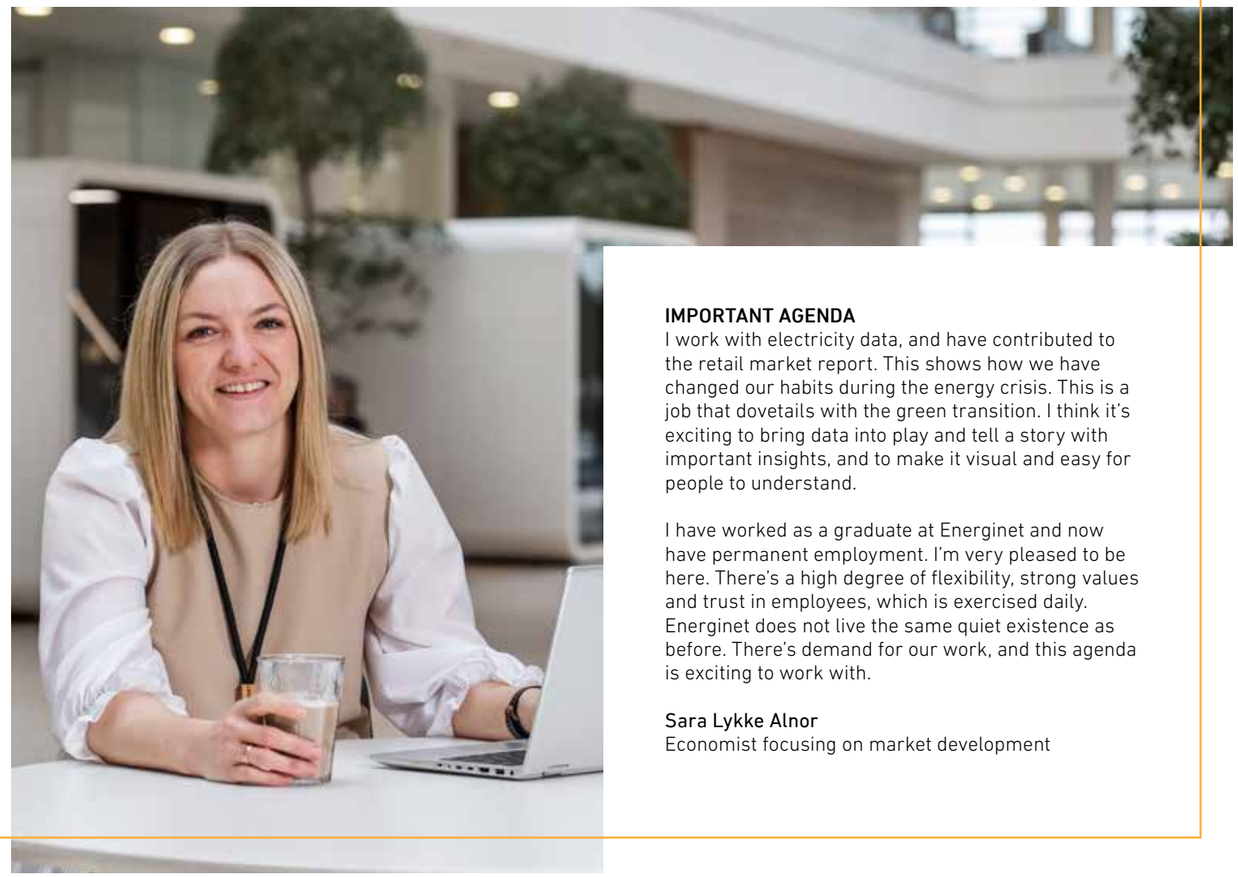
I draw on my IT background and understanding, but it's not only in the technical sphere that we need to succeed. We have to choose the people who fit the team, and ensure that they are thriving and want to stay here. That the employees in Hamlet develop and feel that they are working on the tasks where they belong. The human element and the work of building up the organisation are incredibly exciting.

Anders Leby
Agile People Leader in the platform development project Hamlet

FANTASTIC WORKPLACE
I was employed during the development of the new compressor station in Everdrup. This is a key part of Baltic Pipe and has to pump the gas on to Poland. When the war broke out in Ukraine, time became the most important factor. We are in operation now, and in the process of building up a new workplace, where we need to work out how to operate and maintain the substation. It's extremely exciting to be a part of the project.

Energinet was recommended to me by others, and it has turned out to be a fantastic workplace. We experienced tremendous work pressure during Baltic Pipe, but we were well taken care of. There is more balance in the work tasks now. We have flexible conditions, and Energinet does a lot to retain, train and engage its employees.

Steffen Jakobsen
E-Technician at Everdrup compressor station



IMPORTANT AGENDA
I work with electricity data, and have contributed to the retail market report. This shows how we have changed our habits during the energy crisis. This is a job that dovetails with the green transition. I think it's exciting to bring data into play and tell a story with important insights, and to make it visual and easy for people to understand.

I have worked as a graduate at Energinet and now have permanent employment. I'm very pleased to be here. There's a high degree of flexibility, strong values and trust in employees, which is exercised daily. Energinet does not live the same quiet existence as before. There's demand for our work, and this agenda is exciting to work with.

Sara Lykke Alnor
Economist focusing on market development

A HUGE TASK TO ENSURE ENERGY IN TIME

Energinet is expanding the electricity grid all over Denmark. 3300 km of new electricity connections are in the pipeline. Excavators are already digging in places, and soon to start in others.
Seventy high-voltage substations will be either expanded or newly built, so that new solar cell farms, wind turbines and large electricity consumers, such as hydrogen plants, can be connected.

There is activity everywhere. But this is just the beginning. Much more will be coming in the years ahead.

Between 2023 and 2026, we will invest DKK 41 billion in the electricity transmission system. In many ways, the future will turn the whole power system upside down. Power will be generated in parts of Denmark that lack both the local consumption to use it and power connections with enough capacity to transmit it elsewhere. Electricity generation and consumption will also be multiplied, as we acquire electric vehicles and heat pumps, and need green electricity for things like green fuels for planes, ships and industry.

In order to meet the Folketing's ambitious 2030 goal, all parts of society will have to pull together in the right direction, and quickly.
Energinet is working on many different solutions to ensure energy is available in time.

FUTURE-PROOFING THE POWER GRID
We are building ahead and expanding the electricity grid. In North Jutland, two new 1100 MW high-voltage substations are on the way, even though 'only' 700 MW and 850 MW of solar cell projects are currently planned around these. We are future-proofing these expansions, because we expect more to follow. It is quicker and cheaper to build in one phase.

TURNKEY PROJECTS
We have outsourced projects with a total cost of DKK 10 billion to companies that will supply turnkey power lines and high-voltage substations. Large-scale and standardised solutions are accelerating expansion. We are also creating a common new digital cooperation platform to hold all the documentation, data and 3D models of our plants, making it easy to transfer knowledge among actors.

END-TO-END CUSTOMER JOURNEY
There is a large increase in electricity generation facilities (typically solar cells and large consumers) seeking connection to the electricity transmission grid: 2020: 10 plants, 2021: 25 plants, 2022: 47 plants. Many of these have been processed, and we have developed a more streamlined end-to-end journey for the many new customers, making connection quicker and more transparent.

REDUCED CONNECTION TIME
With what could be called 'alligator clip solutions', new solar cell farms can be connected directly to high-voltage lines and generate power before new high-voltage substations have been built. This will halve the connection time. These solutions increase the risk of disruptions, and cannot be used everywhere, but in some places it is acceptable to operate the power system closer to its limits.

GOOD TEAMWORK
In cooperation with the municipalities of Esbjerg and Varde – which have large-scale electricity generation and consumption projects in the pipeline – we are finding common solutions and interfaces to streamline grid connection, approvals, acquisition of land etc. Experience gained will be disseminated to all municipalities so that the green transition can be accelerated.

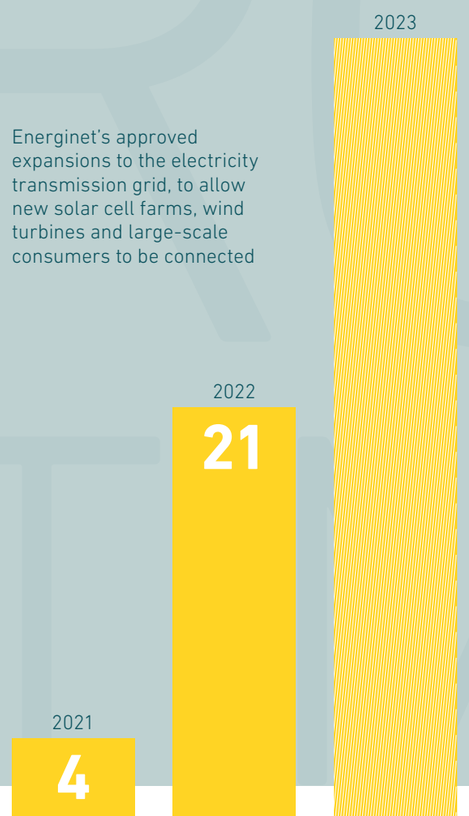
INNOVATIVE REINVESTMENT
We will replace pylons without 'switching off the power' in the lines. At the same time as we are expanding the power grid, much of the existing power grid is reaching the end of its service life. Innovative new working methods are making it possible to work at multiple locations in the grid at the same time, because lines are not taken out of operation, leaving supply dependent on fewer lines.

THINK BIG
The Danish Folketinget's decision to establish 10-15 areas around Denmark for more energy farms will accelerate the transition. The energy farms are expected to meet much of the need for new green power in 2030. RE zones make it possible to implement large-scale expansions to the electricity grid in advance, and be ready before or at the same time as solar cells or wind turbines are installed.

INTERNATIONAL COOPERATION
Whole new ways to create stability in the electricity system need to be found, so that short-circuits and other faults do not lead to major outages. Wind turbines and solar cells are based on inverters, which behave very differently to traditional power stations. Energinet is working with researchers, suppliers and TSOs in several international forums to find solutions for the future.

LONG-TERM PLANNING
Due to the dramatic acceleration in the expansion of green energy towards 2030, we are bringing forward projects in the long-term development plan. Many of the plants that quite recent analyses predicted had to be ready by 2040, must now be ready by 2030. Plans are in place for the future power grid, but they are being executed more quickly.

Energinet's approved expansions to the electricity transmission grid, to allow new solar cell farms, wind turbines and large-scale consumers to be connected



INTER-AGENCY COOPERATION
We are working with the Danish Environmental Protection Agency and the Danish Energy Agency to reduce the processing time for the many construction projects needed to reach the Danish Folketing's 2030 goal. This involves greater inter-agency coordination and input to legislative changes – for example to allow us to acquire land and property earlier in the project phase.

INTELLIGENT UTILISATION
Data and digitalisation are central to ensuring efficient and secure operation of the energy systems. For example, an array of sensors on overhead lines can provide temperature measurements and thus real-time information on line transmission capacity. This will mean that transmission capacity can be increased in cold or windy weather, allowing even more power from solar cells and wind turbines to be integrated.

DYNAMIC RESERVES
A new Nordic collaboration aims to ensure a better and cheaper electricity supply. The Nordic TSOs buy many reserves each day, which are standing by in the event of a short-circuit, power station outage, weather deviation from the forecast, etc. As the electricity system becomes increasingly driven by wind and solar power, we will not buy fixed amounts of reserves. We will instead forecast the varying needs and the possibilities of utilising reserves across borders in the Nordic countries on an hourly basis.

ENORMOUS AMOUNTS
Solar cell farms with as much capacity as a large power station, and new electricity consumers that will double Denmark's electricity consumption. Enormous amounts of consumption and generation are to be added to the electricity transmission grid: 2020: 1.8 GW (1.6 GW generation, 0.2 GW consumption), 2021: 7 GW (3.7 GW generation, 3.3 GW consumption), 2022: 9.1 GW (6.7 GW generation, 2.4 GW consumption).
For comparison: Denmark's maximum consumption in 2022: 6.4 GW.

NEW WAYS OF BALANCING
Electricity generation will be multiplied and will often fluctuate as the wind blows, and consumption will grow markedly. This will create much larger imbalances. Secure supply requires balance between production and consumption. We are therefore looking for new, flexible market participants – from electric vehicle owners to large hydrogen factories – who can provide the reserve power and ancillary services for the future power system.

NEW PLANTS BOOST DANISH BIOGAS

Seven new plants, at a total cost of around DKK 773 million, will allow Denmark to establish a completely green gas system at record pace in the coming years.

"While war and the energy crisis have led gas consumption to decline, biogas production has grown markedly in just a few years, and supplied 34 per cent of total consumption in 2022. This means that there are now branches in the gas distribution grid where more biogas is produced at times than local consumers can utilise. During these periods, there is a risk that biogas production will have to be curtailed, or excess gas flared – and this problem will only increase as biogas production continues to grow," says Peter Hodal, Director of Gas Transmission, Energinet.

The solution is plants that can move the locally produced biogas up into the gas transmission grid, so that the green gas is not trapped in local pockets, but can move freely around Denmark.

For historical reasons, these are called 'reverse-flow plants', but that name is starting to be a little misleading, notes Peter Hodal.

"We are in the process of turning the entire gas system upside down, so the name for these plants should probably reflect the fact they will bring the gas 'forward' to consumers in the future, and not 'back' to the system," he says.

When the Danish gas system was built in the 1980s, its purpose was to transport natural gas from the North Sea to Denmark's CHP plants, companies and private households. North Sea gas landed in West Jutland and flowed around Denmark and towards Sweden and Germany in large transmission pipelines. The gas is under high pressure in these transmission pipelines, partly to compress it, and partly to 'push' it around in the system. When the gas enters local distribution systems, it is transported in smaller pipes and under lower pressure.

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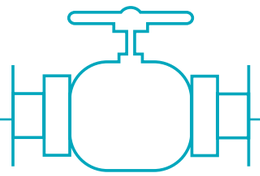


POLICY GOALS
The Danish Folketing has set the goal that all gas in Denmark should be green by 2030, and that no homes in Denmark should still be heated by gas-fired boilers from 2035.

However, in just a few years, biogas has to completely replace fossil natural gas in Danish consumption. In order for the locally produced gas to move from the gas 'highways' onto the 'motorway network' and thus flow around the country, it has to be compressed and the pressure raised markedly. Otherwise it cannot physically flow into the gas transmission system.

Until the new plants come online in 2024-2026, Energinet and Evida – the public enterprise responsible for the Danish gas distribution grid – are working on temporary solutions to prevent excess gas arising in local biogas pockets in the short term, which could have to be flared, explains Henrik Jensen, CCO of Evida.

"The rapidly declining gas consumption in industry and household heating combined with the rising volume of biogas is turning the gas system on its head. It's therefore more important than ever to improve and future-proof the gas system, so we can handle increasing volumes of green gas."

"We have a major focus on solutions that raise capacity in our gas system as quickly as possible, so biogas producers are not forced to ramp down production, and the advance of green gas in Denmark is not slowed," he says.

At Karup, Evida will adapt two compressors that have been ordered, while Energinet handles the rest of the connection to the transmission grid, to create a temporary solution to alleviate biogas pockets in the local area before the final plant at Herning is ready. Energinet is also investigating the possibility of expediting construction of some plants, so that locally produced biogas flows into the transmission system and round the country at an earlier date. Local market solutions that could alleviate the problem are also being explored.

ODORANT MUST BE REMOVED

Locally produced biogas not only needs to be raised to higher pressure in order to move from the gas distribution grids into the gas transmission grid. It is also necessary to remove the odorant that is added before the gas reaches consumers. The gas itself is odourless, and the odorant enables consumers to detect gas leaks. Odorant is currently added when natural gas moves from the transmission grid into the local distribution networks, or at the biogas plants. When gas from the distribution systems is to be injected into the transmission system, the odorant must be filtered out, as it might otherwise cause problems.

The Danish gas system is directly connected to Poland and Germany, which do not want odorant in the transmission systems, as it can affect valves, measuring equipment and gas storage facilities. It is therefore necessary to remove the odorant when gas from the local gas distribution systems is fed into the gas transmission system, for export reasons also.

THE NEW REVERSE-FLOW PLANTS WILL BE BUILT IN

North Jutland
Construction of a new M/R (meter and regulator) station at Haverslev, March 2024

New compressor station at M/R Haverslev, June 2026

Central Jutland
At M/R Herning, March 2025

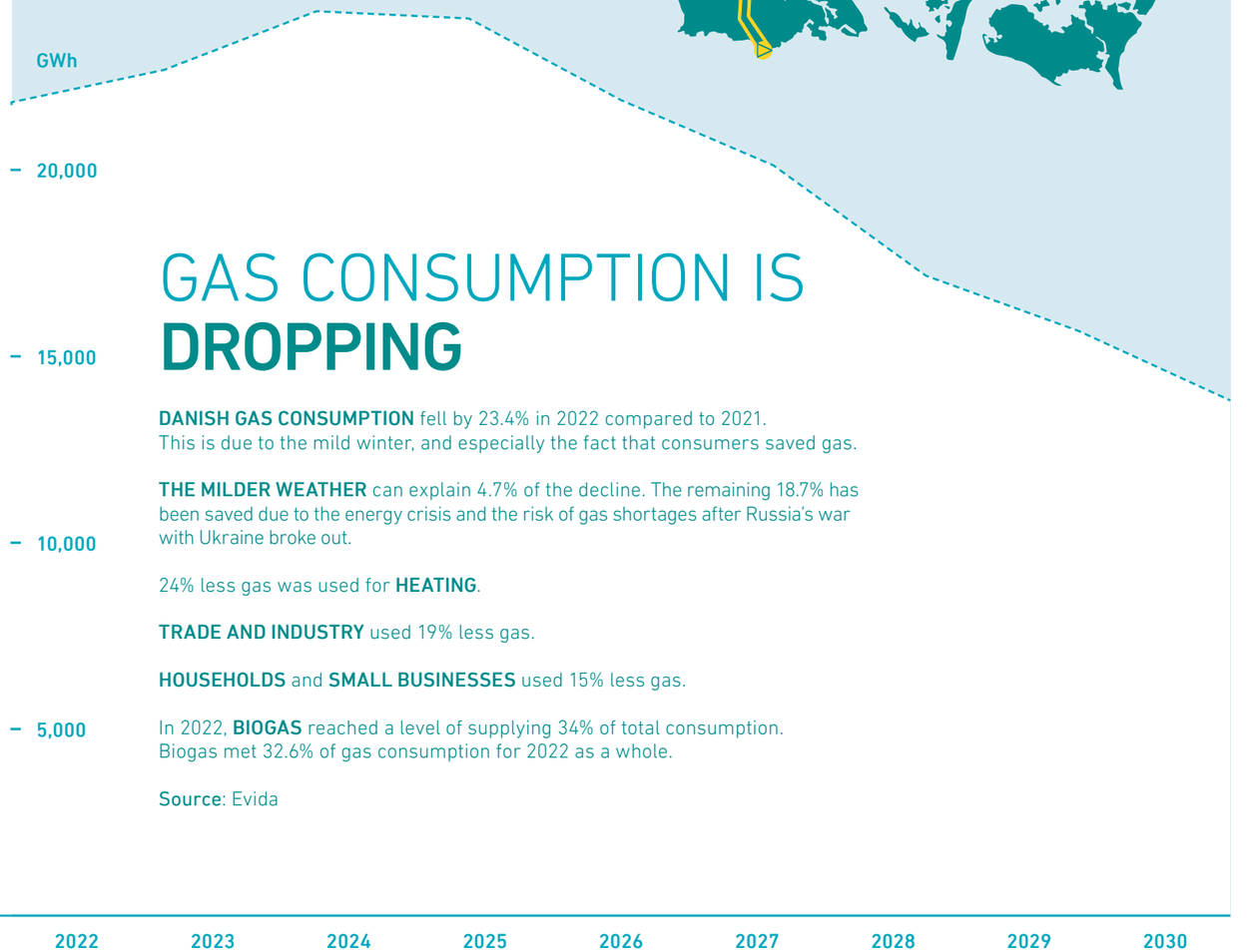
Funen
At M/R Vissenbjerg, September 2025

Zealand
At M/R Køge, December 2025

South Jutland 1
At M/R Nørskov, March 2026

Southern Jutland
At M/R Frøslev, September 2026

South Jutland 2
At M/R Ll. Selskær, December 2026



GAS CONSUMPTION IS **DROPPING**

DANISH GAS CONSUMPTION fell by 23.4% in 2022 compared to 2021.
This is due to the mild winter, and especially the fact that consumers saved gas.

THE MILDER WEATHER can explain 4.7% of the decline. The remaining 18.7% has been saved due to the energy crisis and the risk of gas shortages after Russia's war with Ukraine broke out.

24% less gas was used for **HEATING**.

TRADE AND INDUSTRY used 19% less gas.

HOUSEHOLDS and **SMALL BUSINESSES** used 15% less gas.

In 2022, **BIOGAS** reached a level of supplying 34% of total consumption.
Biogas met 32.6% of gas consumption for 2022 as a whole.

Source: Evida

THE GREEN POWER SYSTEM'S ENORMOUS CHALLENGE

HOW DO WE MAINTAIN BALANCE?

The green transition, green energy and green hydrogen production all sound so good. But the green transition also entails the huge and potentially expensive challenge of balancing the future power grid. Because as we get more electricity from fluctuating sources such as wind and solar power, it may be necessary to purchase lots of reserve power and flexibility. And many potential providers of these ancillary services do not yet realise that they have something to sell.

Green energy for a better world!

This is the vision everyone at Energinet has in mind when they go to work each day.

But some Energinet employees might be tempted at times to change the words to 'Green energy for a better world – with major challenges'.

The employees involved in balancing the electricity system work each day to solve one of the most difficult aspects of the green transition:
The fact that green energy is more unstable, with a risk of many large imbalances.

"There are lots of complicating factors in an electricity system based 100 per cent on renewable energy. Ensuring balance and stability in the future power system will be a huge task," says Kia Marie Jerichau, Head of Flexibility and Balancing in System Operation at Energinet.

Ancillary services maintain balance
She is responsible for the purchase each day of the necessary ancillary services to keep the power system in balance at 50 hertz.

The relationship between power generation and consumption is constantly under threat from imbalances and potential technical faults, that could result in grid outages. In these situations, the purchased reserves (ancillary services) are activated – in a few seconds or a few minutes – to make adjustments, up or down, and restore balance in the gird.

Ancillary services can take the form of reserve capacity that is constantly available, eg from large batteries – or a power station that is standing by to supply more energy.

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This whole balancing act is difficult enough already. But it will become even more challenging in just a few years when the power system is to run purely on renewable energy:

"From a balancing perspective, having fewer thermal power stations involved makes things difficult, because they are good at providing ancillary services. They are easy to ramp up and down. At the same time as we are losing some of the traditional providers, we have to buy more because the need is increasing. This is because electrification means generally higher electricity consumption, and because our energy sources will fluctuate more, creating more and larger imbalances," says Kia Marie Jerichau.

She also mentions the obvious challenge in a system based on a lot of wind and solar energy: What happens when there is no wind or sunshine? Who is going to be standing by as reserve and balance the system?

New participants, new models
All this means that even more ancillary services may have to be purchased. Many more. And that could be expensive. Or rather – even more expensive than today. Because the cost of ancillary services in Denmark has already almost doubled in just one year, from DKK 1.4 billion in 2021 to DKK 2.7 billion in 2022.

But it is a difficult market to make large purchases in. Many potential providers do not even know that they have a product to sell.

"Many of the actors that we expect to provide system services in the future do not even know that ancillary services exist. They are not electricity market professionals. There may therefore be a need for intermediaries. For example, a platform that pools all the electricity consumption flexibility from buildings and offers this to Energinet. Or a charging station vendor that comes up with a smart way whereby they can offer flexibility to Energinet. Then electric vehicle owners would not have to know much about how this works – except that they reap a price benefit. There is a need for new business models and new types of market participants," says Kia Marie Jerichau.

Power-to-X plants can contribute
She would also very much like to see help from a specific group of future large-scale electricity consumers – the Power-to-X plants, which will use electrolysis to convert large quantities of green electricity into hydrogen or other green fuels. She would like to see greater awareness of the ancillary services market among these actors, due to a mix of social responsibility and business sense:

"Everyone thinks that Power-to-X is so good – and it is good that many actors want to convert green electricity into green fuels for ships, aeroplanes and industry. But these plants will not make a positive contribution to the green transition unless their consumption is also flexible. Otherwise they simply create a huge new demand for power. However, there is a financial incentive to not merely produce hydrogen in a steady stream, but also contribute flexibility. I look forward to us managing to communicate this even more clearly, and the developers of the large Power-to-X plants becoming aware of it – for the sake of their own business and for society," says Kia. She notes that several Power-to-X plants are expected to be operated with essentially constant electricity consumption throughout the year, only shutting down during the worst price peaks.

But the plant owners can achieve a significant reduction in the costs of hydrogen production through more flexible operation, combined with providing ancillary services. However, this will require additional electrolysis and storage capacity, or flexible hydrogen sales.

We'll find a way
Despite the major challenges, Kia Marie Jerichau remains optimistic. Because there is a lot that she and Energinet can do in relation to ancillary services:

For example, there are technical benefits to be reaped from preparing better and more accurate forecasts for consumption, and for solar and especially wind power generation, which vary from day to day. If you know how large the imbalances will be tomorrow, it is easier to buy the right amount of ancillary services.

There are also good reasons to support the large common markets for ancillary services in the Nordic countries and Europe. This means more participants to buy from and thus lower prices.

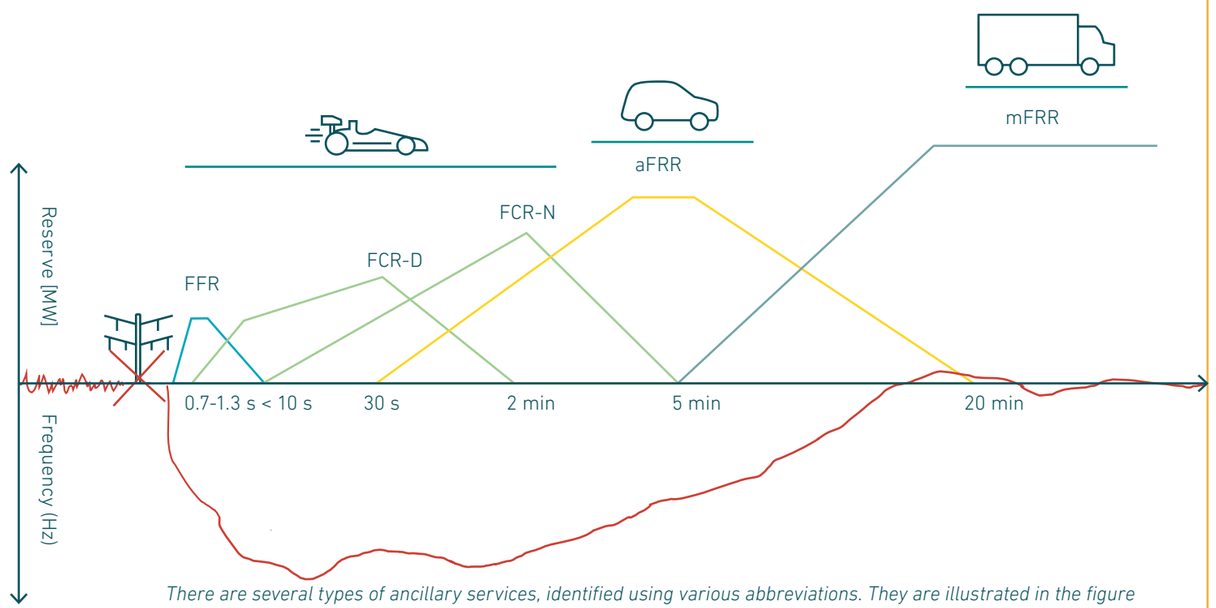
And speaking of markets, Kia Marie Jerichau also sees great potential in Energinet helping new actors to enter the ancillary services markets:

"How do we ensure that the people behind new technologies like Power-to-X find it interesting to provide ancillary services? Have we created any barriers that make it difficult to participate in the ancillary services market? Perhaps we need to give providers more assistance with their business models and advise them on how they can use the electricity market?," she suggests.

Overall, she wants to increase Energinet's focus on customers, collaboration and partnerships that can lead to new solutions. And to be bolder and more inquisitive, reaching out and involving those Energinet would like to see enter the market.

Kia Marie Jerichau is also confident that while the task of balancing the future power system is big, it is not insoluble:

"There's no point hiding the fact that we face major challenges. But while it will be difficult, we will find solutions – and ones that will make the green transition affordable."



There are several types of ancillary services, identified using various abbreviations. They are illustrated in the figure above using vehicles. The racing car represents small, responsive reserves, while the truck is a bit slower, but carries more load when it starts to move. The figure shows how a frequency drop (red curve) occurs in the event of sudden imbalances or outages. Various ancillary services are then activated to restore the frequency to the 'healthy' level (50 Hz). Frequency products must quickly add power to the system to mitigate the frequency drop and prevent it from falling to a critical level. The more energy-intensive services (aFRR and mFRR) have to relieve the frequency services, so these are available again to mitigate new frequency drops and restore balance.

WHAT ARE ANCILLARY SERVICES?

- Ancillary services are a collection of products Energinet purchases in order to ensure balance between electricity generation and consumption at all times of the day.
- It is impossible to precisely predict and plan electricity generation and consumption, and ancillary services are used to fill any gaps that arise as a result. If Energinet did not have ancillary services available to it, the power grid would become overloaded and damaged.
- Ancillary services can be provided by entities such as shopping centres, power stations, swimming pool centres, hydrogen plants, heating plants, ventilation systems and large batteries.

I WANT TO PROVIDE ANCILLARY SERVICES – WHAT DO I DO?
If you have plant that can operate flexibly, you can probably help in balancing the green transition – and even earn money doing so. There are two ways to find out more:

1. You can read more (in Danish) about ancillary services on Energinet's website (www.energinet.dk/systemydelser). You can do a test here and find out how you can offer your flexibility to the power grid.
2. Contact Energinet on electricitymarket@energinet.dk for more information.

NEW TECHNOLOGY IN OLD POWER STATIONS CAN HELP **BALANCE THE POWER SYSTEM**

A new energy storage technology, whereby heat from green electricity is stored in molten salt, can also provide ancillary services as a side benefit. Energinet is therefore on the side lines, offering guidance to Hyme Energy, the company developing the technology.

Energinet needs a large and mixed palette of ancillary services in order to safeguard the future power system against increasing imbalances.
One of the more interesting elements in the palette is a new technology involving salt heated to 600-700 degrees and old CHP plants. This technology may be able to address some of the major challenges in the future green power system, driven by fluctuating wind and solar power sources.

The concept is being developed by the Hyme Energy start-up company. The plan is for the first large Hyme plant to be ready to produce and store energy – and provide ancillary services – in 2025 or 2026.

"We exploit the fact that we can use electricity to heat salt to very high temperatures, thereby storing energy. When the need arises, we can extract the energy and use it to drive a steam turbine – the classic method for generating electricity in CHP plants," explains Nis Benn, Commercial Director at Hyme Energy.

He sees a clear match between Hyme's solution and several major challenges presented by a future 100% green energy system: security of supply and energy storage. Hyme's technology can be deployed in existing CHP plants, utilising the plants' infrastructure and connection to the electricity grid. Regarding storage, the Hyme model proposes a way of best utilising green energy – by storing it thermally when cheap solar and wind power is available, for later use when there is a shortage of electricity and the price is therefore higher. Hyme technology allows gigawatt hours of energy to be stored, from day to day and up to 7-10 days.

Test on Bornholm
The first prototype will be built in Esbjerg in 2023. In 2024 and the ensuing years, the Hyme model will be tested on Bornholm as part of an EU project, under which a disused power station unit is converted into a 'green battery' and will supply electricity and hot water to Rønne.

Hyme's business model involves selling its plants to utility companies which supply heat and power to consumers – and which already receive income from the sale of ancillary services to Energinet. Hyme therefore needs help from Energinet to develop its plants, as Nis Benn explains:

"Our customers ask about the possibility of providing ancillary services using our plant. They ask many technical questions, and want to know whether the plant fulfils Energinet's requirements. So we need to understand how to design our plants in order for them to be able to provide ancillary services in the market that will exist in 2025-2028."

Uncertain market
He reports that Hyme has experienced great openness and a service-minded approach from Energinet in the process of understanding and adapting to the ancillary services market. But there are also challenges when a future actor such as Hyme needs guidance from Energinet.

Firstly, the markets for ancillary services are changing – from national to international markets, and the bidding structure for ancillary services is also changing. It is uncertain what exactly this will mean for the various market participants, which makes it difficult for Energinet to advise them.

"We would also like Energinet to think more about our type of energy storage, ie 12-24-hour storage facilities. The integration of energy storage facilities into the ancillary services markets is still in an early phase, so we await further progress and more priority being given to renewable energy in the market framework for mFRR and aFRR (energy-intensive ancillary services, ed.)," says Nis Benn.

Line Kamp Bräuner, Chief Economist in the Balance Market department, is one of Energinet employees who works with Hyme. She explains Energinet's great interest in the Hyme model:

"Hyme is innovative and their approach holds great potential. Their plants can address the storage problem, making them a vital balancing resource. Hyme is exciting for our future in relation to ancillary services and general energy storage."

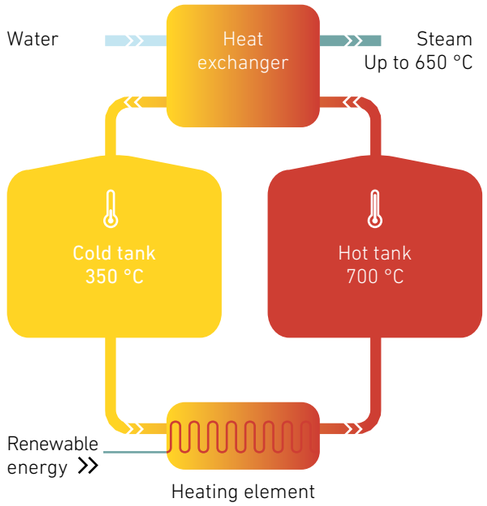
> Our technology is suitable for large-scale energy storage. But we need to understand how to design our plants so they can provide ancillary services.
>
> **Nis Benn**
> Commercial Director at Hyme

HYME
Hyme is based in Copenhagen and was founded in 2021. It is an offshoot of Seaborg Technologies, a nuclear power company.

In the Hyme model, energy from wind and solar energy is stored in a special type of salt – sodium hydroxide (drain cleaner) – which has been known as a good material for energy storage for more than 60 years. It can be heated up to 1400 degrees before it boils, and it is cheap, as it can be produced from salt water and is a by-product from chlorine production.

The great challenge of using sodium hydroxide – that it corrodes and breaks down stainless steel – has been solved, according to Hyme, through several years of research at Seaborg, which has patented the technology for use in its nuclear reactor.

See www.hyme.energy for more information.



In the Hyme energy storage model, energy is stored by converting electricity from renewable energy into heat using heating elements. Salt from the cold tank is circulated through the heating elements and heated from 350 to 700 °C. The salt is then stored in the hot tank for up to several days.

When the stored energy is needed, it is retrieved by circulating the hot salt through a heat exchanger, where the heat is transferred to water, converting it to steam at up to 650 °C. Steam can be used directly in an industrial process, or drive a turbine and supply electricity and heat. The cooled salt is pumped back into the cold tank until the next storage cycle.

Illustration Hyme Energy
Credits Kirt x Thomsen

THE FUTURE

ENERGY SYSTEM CALLS FOR **NEW PAYMENT MODEL**

A new green energy system will cost a lot of money, but can become needlessly expensive and inefficient if we fail to ensure that the changes are accompanied by new frameworks and conditions, which make it attractive to electricity consumers and producers alike to give the green transition a helping hand. And which lead to a fair distribution of the costs of operating and expanding the power grid.

New energy system – new tariff design
A pure energy tariff with payment per kilowatt hour. This has been the relatively simple one-size-fits-all model for Energinet's tariffs since the company was established in 2005. The current tariffs were designed at a time when power was primarily generated at central power stations, located close to large cities and consumption centres. The grid capacity and the locations of electricity generation plant were primarily determined in relation to consumers, who have therefore also paid the bulk of the costs of operating and developing the power grid.

"The tariffs date from a time when power generation could be quickly adjusted to match consumer demand. They do not take into account whether consumers use electricity when the grid is under least load, or how much available capacity they want. We are moving rapidly towards a power system where electricity generation depends on wind and solar power, and is thus much less flexible. Consumption therefore has to be flexible instead. We have therefore decided to change the way we set tariffs," says Marie Budtz Pedersen, Senior Manager in System Value and Regulation at Energinet.

What will make a big difference to the power grid balance is particularly the electrification of new types of more flexible consumption, that can ramp down consumption on a windless evening and ramp it up when there is abundant cheap green power available.

"Power-to-X plants are a good example. These will typically be large plants that use enormous amounts of electricity to produce hydrogen or other green fuels, and can respond very flexibly to the electricity price. A uniform energy tariff placed on top of the variable power price will make electricity consumption less flexible than is desired. The same applies to large heat pumps and electric boilers. The local grid companies and Energinet must ensure that this new type of flexible consumption is actually connected flexibly, and based on new tariff conditions that promote the desired flexibility, to the benefit of the power system overall and society," notes Marie Budtz Pedersen.

New producer tariff aims to promote the right infrastructure
An efficient green transition largely involves building the right amount of infrastructure, but also fully utilising existing infrastructure. Electricity generators therefore have to benefit from placing wind turbines and solar cells close to consumption, or where there is room in the power grid to better utilise existing cables and power lines. Optimisation can also be achieved by placing solar cell and wind farms together geographically. This allows them to share connection capacity to the public electricity grid. Wind and solar power actually complement each other well, as high production of wind and solar power at the same time is quite rare. For example, solar cell farms typically generate most power in the summer months, while wind turbines are most active in the winter months.

"The capacity in the electricity grid is in high demand, so it's important that we utilise existing cables and power lines as much as possible. Energinet has therefore introduced a new tariff model for electricity generators. This takes into account the higher costs of placing plants in areas where the electricity grid is already fully utilised – while the tariff is lower in parts of the country where the existing grid has spare capacity and consumption is not far away."

There is also a need to create better balance and a fairer distribution of the costs of developing and operating the Danish electricity system, as it changes to become fully green.

> In future, grid users will pay less for how much electricity is actually transported in the grid, and more for the capacity they want available to them – much like we pay for bandwidth on an Internet connection today.
>
> **Marie Budtz Pedersen**
> Senior Manager in System Value and Regulation at Energinet

"The new tariff model must ensure that the electricity generators contribute to both the specific costs associated with connecting their plants, and the necessary reinforcements to the grid.

In future, grid users will pay less for how much electricity is actually transported in the grid, and more for the capacity they want available to them – much like we pay for bandwidth on an Internet connection today," says Marie Budtz Pedersen.

The new producer payment model was approved by the Danish Utility Regulator in December 2022.

WHAT ARE TARIFFS?
Tariffs are a payment for the services provided and costs incurred by Energinet and the grid companies, as they operate and manage the power grid cables running throughout Denmark and transmit electricity to consumers and businesses. See www.energinet.dk/tariffer (in Danish) for more details.

IMAGINE ...

Imagine a digital platform that connects the electricity and gas motorways in a single Danish energy system, and makes it possible to control and transport energy from all offshore wind farms, gas storage facilities, international connections, power stations, solar cells, biogas plants and onshore wind turbines. Picture Denmark's control centres for electricity and gas, which draw on all this data every minute, in combination with weather forecasts for solar and wind power and international market predictions for electricity and gas consumption. And consider also the rising cyber threat from hackers around the world.

If you picture all these elements, you will have a general idea of the task Energinet has began to undertake at a fast pace, in one of its largest IT investments to date.

Everything has to communicate
"A modern energy supply requires secure and robust digital infrastructure just as much as it needs power lines, cables and pipes," says Signe Horn Rosted, Group Senior Vice President, Tech & Innovation, Energinet.

"We have to be able to transmit and share an unprecedented amount of data, because the future green energy system will be made up of far more units than today, which supply or draw on the system. The increasing complexity of the energy supply also demands intelligent and automated control in our control centres. In other words, everything has to communicate if we are to ensure a stable energy supply in Denmark in the future.

At the same time, there is a huge potential for using digital solutions and energy data to promote green consumer behaviour and ensure optimal and sustainable utilisation of our physical plant and distribution lines. We are therefore building a whole new digital platform for our supply-critical systems," she explains.

High cyber security requirements
The recent war and supply chain crisis in Europe has shown us, more than ever before, that energy supply is a critical nerve in society, which can unfortunately also become a target. An extremely high level of security is therefore essential for supply-critical data and IT systems.

"In order to withstand the rising cyber threat, we are building the new platform with a modular structure. This makes it far easier to monitor and protect the individual elements, and we can continuously replace modules with the latest and most secure technology. With a modular structure, we also reduce the number of interfaces through which data must pass. This significantly reduces the risk and impact of harmful attacks," explains Signe Horn Rosted.

Developing and replacing such a crucial part of the IT foundation for the Danish energy system is an enormous task. The work began in earnest in 2022, and the first data and supply-critical IT systems are expected to be transferred to the new platform in 2024.

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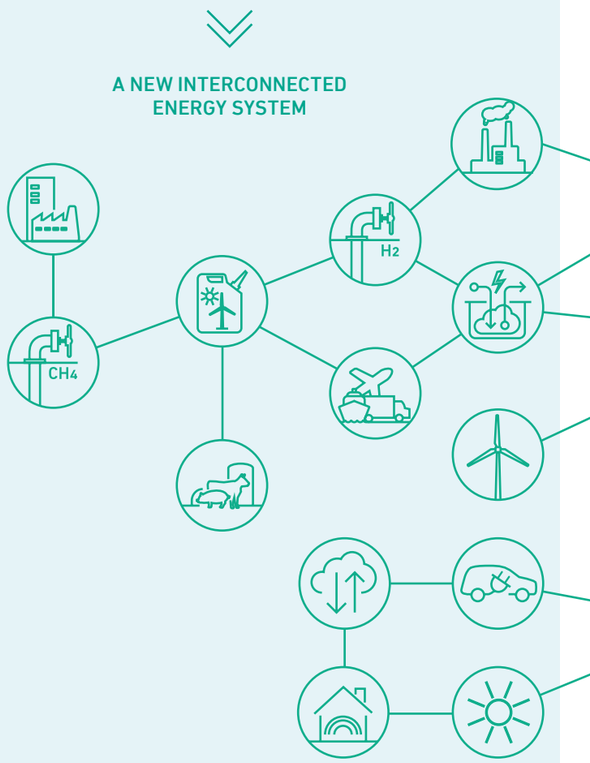
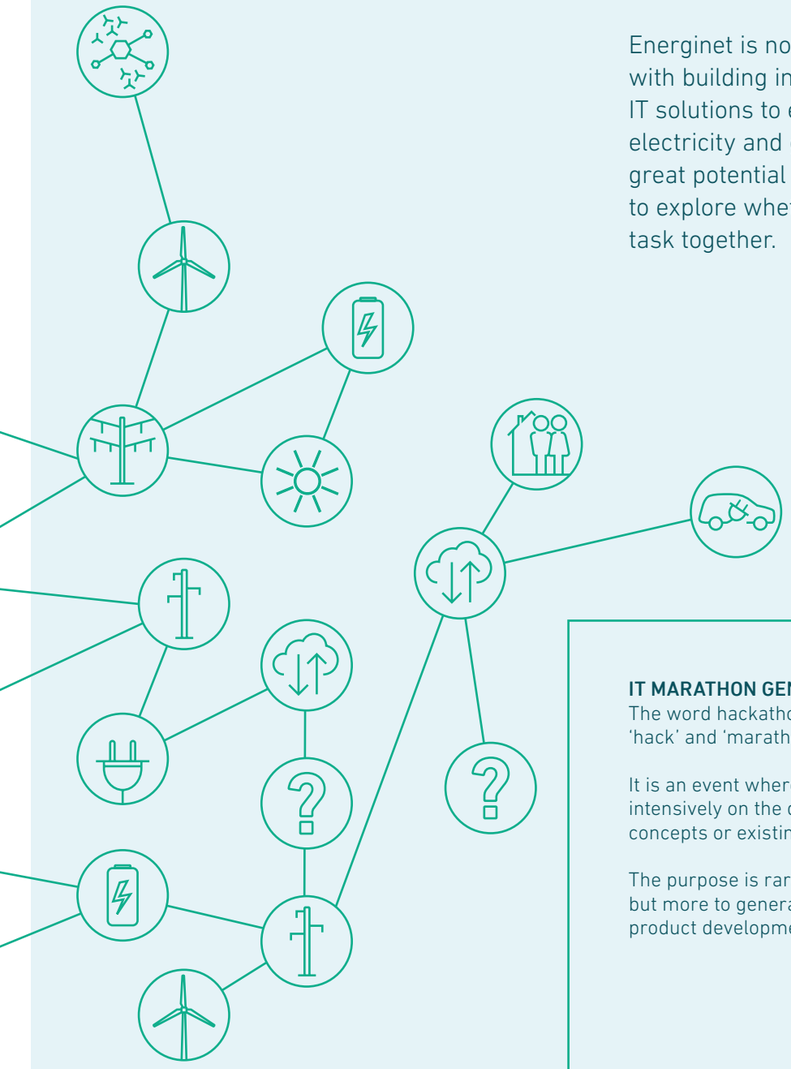
THE ENERGY SYSTEM'S NEW DIGITAL PLATFORM
A new digital platform is needed to support the future green energy system, because far more data has to be handled – quickly and securely.

Energinet is developing and building its digital platform based on modules – a solution that does not exist today. The digital platform is being designed with an uptime requirement as close as possible to 100%.

The future green energy system will be made up of far more units than today, which supply or draw on the system.



INNOVATIVE HACKATHONS WITH GERMAN COLLEAGUES



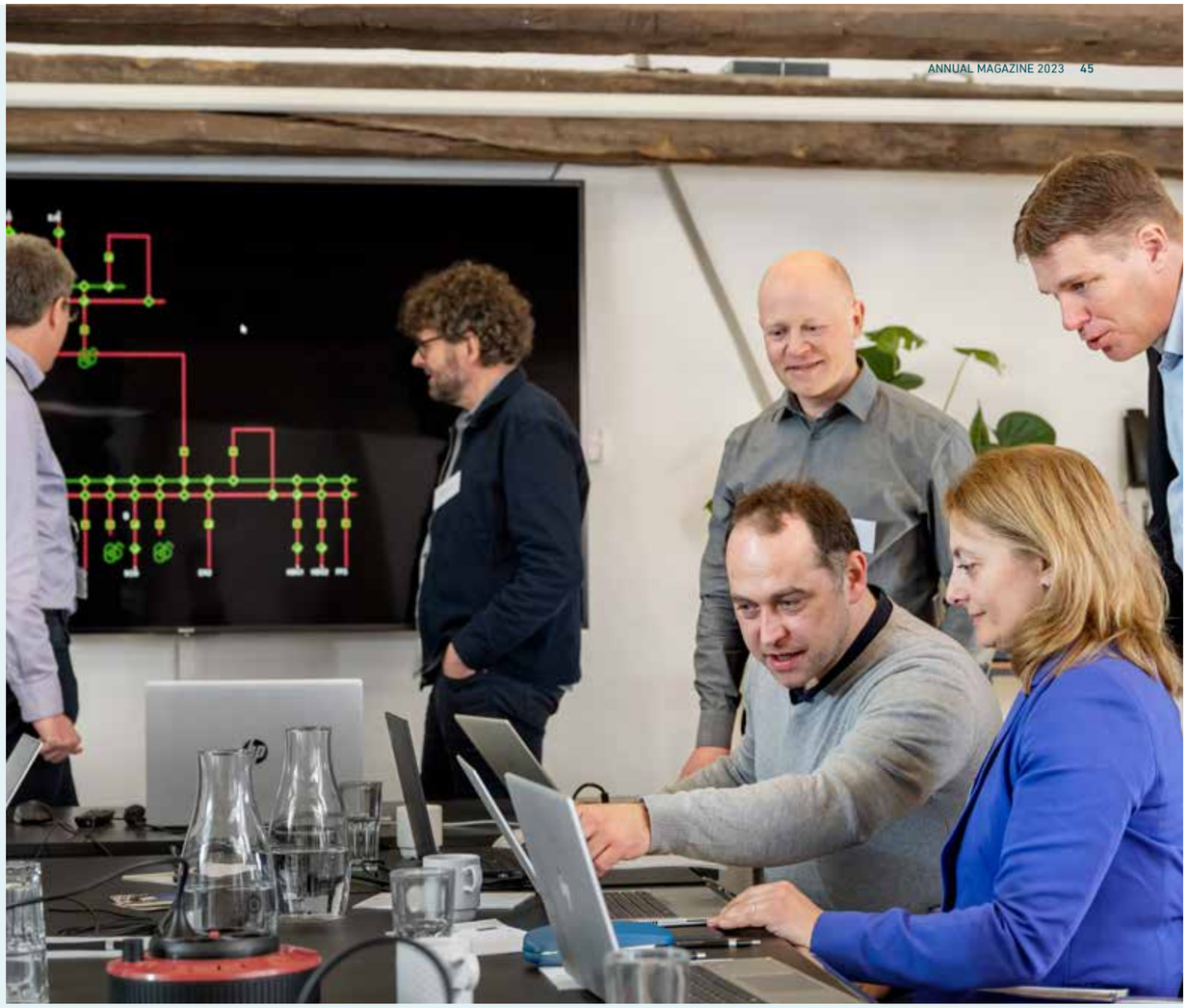
Energinet is not the only entity tasked with building intelligent and automated IT solutions to ensure a stable future electricity and gas supply. We therefore see great potential in working with other TSOs to explore whether we can complete the task together.

IT MARATHON GENERATES IDEAS

The word hackathon is a combination of the words 'hack' and 'marathon'.

It is an event where IT profiles meet and work intensively on the development of prototypes, concepts or existing IT projects within a specific topic.

The purpose is rarely to produce finished products, but more to generate ideas and a basis for actual product development at a later stage.



Hackathons are one of the methods via which Energinet has chosen to explore innovative collaboration. These are held jointly with German 50Hertz and others, who – like us – want to use digital and module-based technology.

"We are performing a complex task that no system operator has done before. It demands teamwork and focus. It's therefore fantastic to experience the great dedication and enthusiasm from people at both Energinet and 50Hertz. We see great value in holding hackathons. Imagine if we can thereby together accelerate the digitisation of the energy system," says Mirko Pracht, Head of Digitisation in System Operation at 50Hertz.

The great benefit of experimental collaboration is that it can accelerate technology development, and allow us to draw on each other's resources. This may help Denmark and other countries, when have to balance an energy system running entirely on renewable energy in the near future.

"The module-based structure of the IT systems enables us to potentially develop our systems in parallel, and make use of elements developed by the other party. This will allow us to achieve synergies at a time when the energy system is rapidly changing. We can potentially identify where to focus our innovative efforts through short, intensive collaboration processes," notes Niels Julskjær, Chief Business Developer at Energinet.

The series of hackathons being held with 50Hertz and other international colleagues are attended by IT developers, IT infrastructure specialists and business analysts, to ensure that the right perspectives are brought into play.

SUSTAINABILITY STARTS ‘AT HOME’

Energinet’s vision of green energy for a better world has never been more relevant. Recent events in Europe have made the green transition more urgent. It has now become clear that green energy is not just the answer to a climate-neutral future, but also to a geopolitically secure world.

The Danish goal is to be almost entirely running on green energy by 2030. So things need to happen fast. Many new plants and connections will have to be built in order to meet the ambitious goals. The operation of Denmark’s electricity and gas systems alone has a major climate impact.

We must therefore be very aware at Energinet of the impacts we have along the way. On the climate, on the environment, on the citizens affected by our construction work – and on our employees, who work on building, developing and operating the Danish electricity and gas systems each day. Overall, it is important that we think about sustainability and security across our entire value chain and organisation.

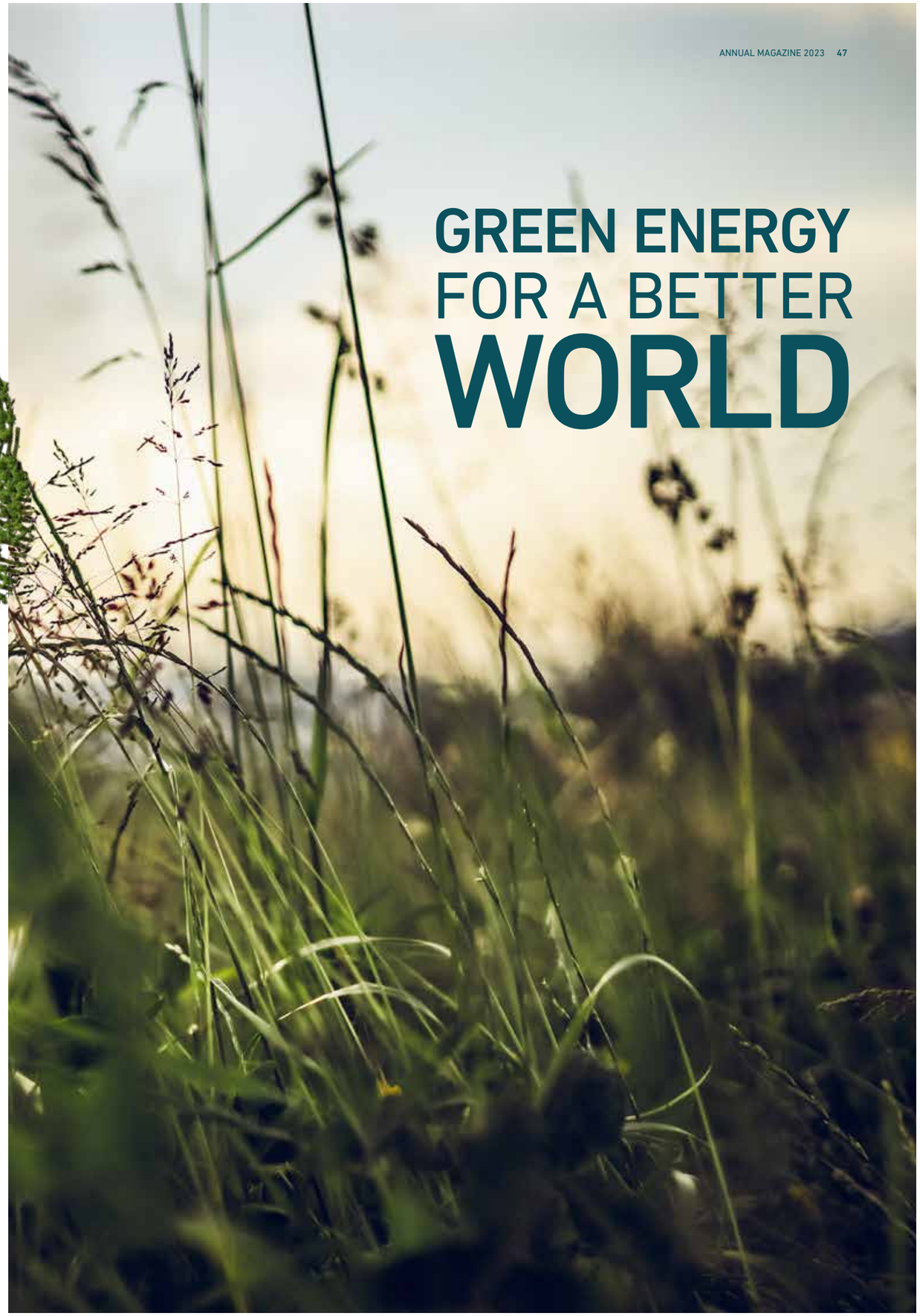
Interdisciplinary cooperation ensures action and ownership

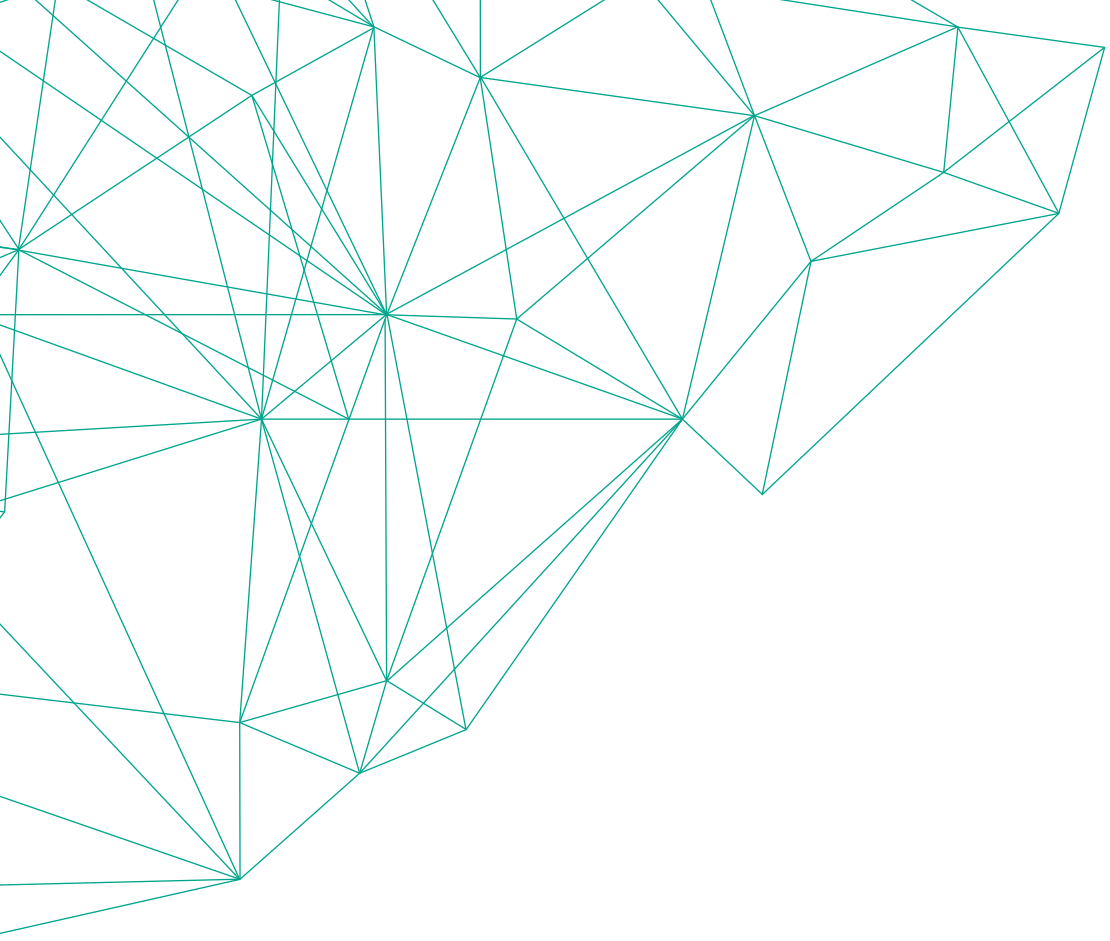
An essential part of the work with sustainability in Energinet is that it is implanted and anchored in all parts of the organisation. This must be considered everywhere decisions are made – in daily operations and in all projects.

One of the initiatives to help ensure this happens is a working group consisting of over 25 employees from all parts of the organisation’s companies and departments. In brief, they must endeavour to ensure that Energinet performs its tasks as sustainably as possible. They will do this by sharing knowledge and ensuring a common framework, processes and activities that meet Energinet’s high sustainability aspirations and expectations, and those of the world around us – including the stricter requirements and legislation regarding corporate responsibility in Denmark and the EU.

Our activities also extend beyond Energinet, for example when we make the same high demands of our suppliers to deliver sustainable solutions.

You can read more (in Danish) about sustainability in Energinet at www.energinet.dk/baeredygtighedsrapport2022





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Energinet is an independent public enterprise owned by the Danish Ministry of Climate, Energy and Utilities.

We are working towards a green transition of the energy systems, so that citizens and businesses can use renewable energy for everything, with a high level of security of supply and at an affordable price.