TÍÐARFEST ÚTBYGGINGARÆTLAN

Main Report

2023

umhvørvisstovan

SEV

Expansion Schedule

Main Report

Model Calculations

Summary

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1. Introduction

The agreement entered between the Minister for Energy Magnus Rasmussen and the negotiating party representing the local government sector and SEV in March 2022 contains a provision that the energy authority and the limited company SEV, in its capacity as grid operator, must draw up and agree on a schedule for public tenders of sustainable energy, so that the tenders and the expansion of the electricity system (grid etc.) are aligned, meaning that the electricity grid in locations where power plants are planned will be expanded to offer sufficient capacity to receive the additional energy.

The working party was established in June 2022 and began organising work. In summary, the work entails producing an updated energy consumption forecast and, based on this, draw up a proposal for a renewable energy expansion schedule over the next five years.

A key component of the energy transition is electrification with a large scale energy consumption shift from oil to electricity. In the Faroe Islands the energy transition is well underway. Household and building heating is shifting from oil boilers to heat pumps at a considerable rate, and transport is undergoing a shift from diesel and petrol vehicles to electric vehicles. Part of the heavy traffic on land can be shifted to electricity and another segment to green fuel, e.g. hydrogen.

Oil independence in the Faroe Islands will also require an energy shift on land. In the manufacturing industry several large and energy intensive plants are, at present, dependent on oil, for example to produce steam. Oil consumption in this industry segment is estimated at 20,000 tonnes per year.

If we look beyond the next five years and taking into account the projected electrification of onshore industry in the Faroe Islands, as well as a shift in maritime energy consumption, where ships and boats switch to some type of green fuel, it becomes clear that the demand for electricity will grow to a volume that will be difficult to meet with onshore wind turbines. Significant developments have been made in offshore wind turbines and the working party therefore recommends launching efforts as soon as possible to look into if and how offshore wind turbines could be placed in Faroese waters.

A crucial element of progress towards 100% green electricity production in the Faroe Islands is a pumped hydro system, which can store surplus energy, particularly wind energy, so that it can be reused at times when insufficient renewable energy is generated. The investment required would total around DKK 1.3 billion. A pumped hydro system is a crucial precondition for continued expansion of wind energy.

The expansion of wind energy could easily be delayed or halted without support from the local population, local government and landowners. In addition, environmental and nature production organisations are needed as allies rather than opponents.

One means of securing land access is expropriation and the authority should acquire this power.

Crucially, any expansion schedule will always be based on a certain set of conditions, which apply at the time when the schedule is drawn up, so any expansion schedule will always be a snapshot in time. If any given conditions change, e.g. if energy usage forecasts change, this will affect the expansion schedule to a minor or major degree. This means that the schedule should be reviewed annually.

One of the fundamental preconditions is a strict linear reduction in CO_2 emissions towards 2030, when no emissions should stem from electricity production.

2. Terms of reference and working party

On March 22nd 2022 the Minister for Energy and a negotiating party representing the owners of SEV signed an agreement on the structure of the energy sector.

Point 5 of the agreement reads: *'The energy authority and the limited company SEV as grid operator shall draw up and agree on a schedule for tenders of renewable energy works, so that the tenders and expansion of the power system (grid etc.) dovetail, meaning that the electricity grid in locations where wind farms are placed shall have sufficient capacity to receive the new energy.*

The first schedule is to be ready in the first semester of 2022 and should encompass expansions for at least the following five years, as well as forecasts for the following five-year period. The expansion schedule is to be updated annually and submitted to the Minister for Energy and the Environment for approval'.

As mentioned in the agreement, we aim for sound, close and trust-based cooperation, so that all future expansions of the Faroese electricity grid are based on robust knowledge-based considerations, which support the green energy transition.

In June 2022 a working party was established to draw up an expansion schedule. The working party is made up of three representatives of The Faroese Environment Agency and three representatives of SEV.

Kári Mortensen, The Faroese Environment Agency

Tina Ragnudóttir, The Faroese Environment Agency

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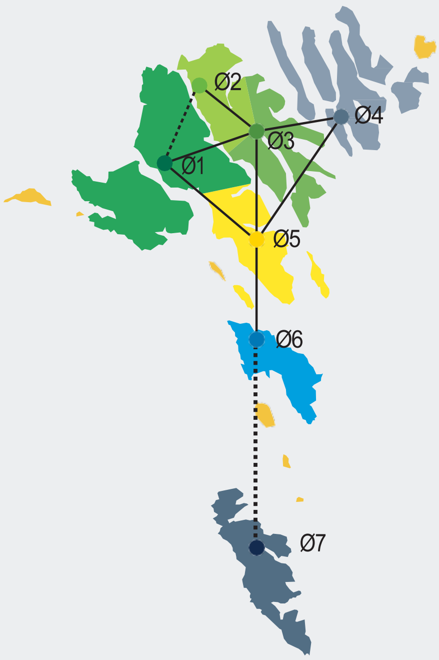
3. Energy consumption forecast

This segment focuses on energy consumption in the Faroe Islands up to 2030. Two forecasts have been prepared. One that is considered the most likely, termed Probable Consumption Forecast, and another that takes into account a swift transition in heating and land transport, as well as a higher rate shift from oil to electricity in industry. The second forecast is termed High Consumption Forecast.

In the forecast the Faroe Islands have been divided into 6 areas, and a special area (Ø3), which does not represent any actual geographic location and is only used for the purpose of modelling. Growth in each separate area is examined in order to arrive at a total growth figure for the entire country.



Area 1
Norðurstreymoy and Vágar

Area 2
Norðureysturoy and Sundalagið

Area 3
Skálabotnur Hub (not included in the forecasts, used only for technical simulation purposes)

Area 4
Norðoyggjar (except Fugloy)

Area 5
Suðureysturoy, Suðurstreymoy, Hestur and Nólsoy

Area 6
Sandoy

Area 7
Suðuroy

3.1 Ordinary electricity consumption forecast

Ordinary electricity consumption is all usage from households and buildings, smaller commercial and industrial establishments, street lighting and the like. Electricity use by heat pumps and electric vehicles is included in a separate forecast and is not considered part of regular electricity consumption. Growing electricity usage in onshore and maritime industry is not included here either.

Probable consumption forecast

The basis used to predict ordinary electricity usage in the probable consumption forecast is growth in the specified land areas in the period 2009-2020. During that period growth ranged from 1.2% (Norðureysturoy and Sundalagið) to 7.0% (Norðoyggjar except Fugloy).

Figure 1 shows that the probable consumption forecast is ordinary usage estimated at approximately 485 GWh by 2030.

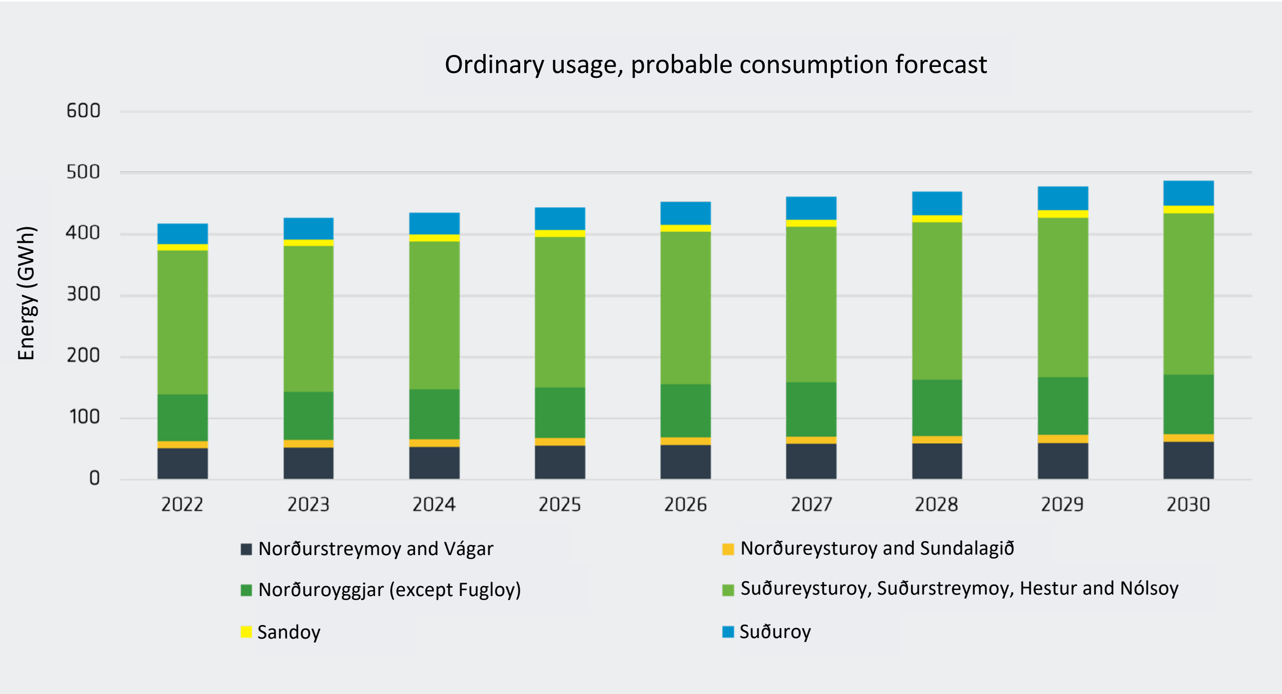


***Figure 1** Ordinary usage, probable Consumption Forecast*

High Consumption Forecast

The basis for forecasting ordinary electricity usage in the High Consumption Forecast is an average growth in the different areas of 1.2% (Suðuroy) - 14.4% (Norðuroyggjar except Fugloy) in the period 2017-2020. Figure 2 shows that in the High Forecast ordinary usage is estimated at approximately 550 GWh by 2030.

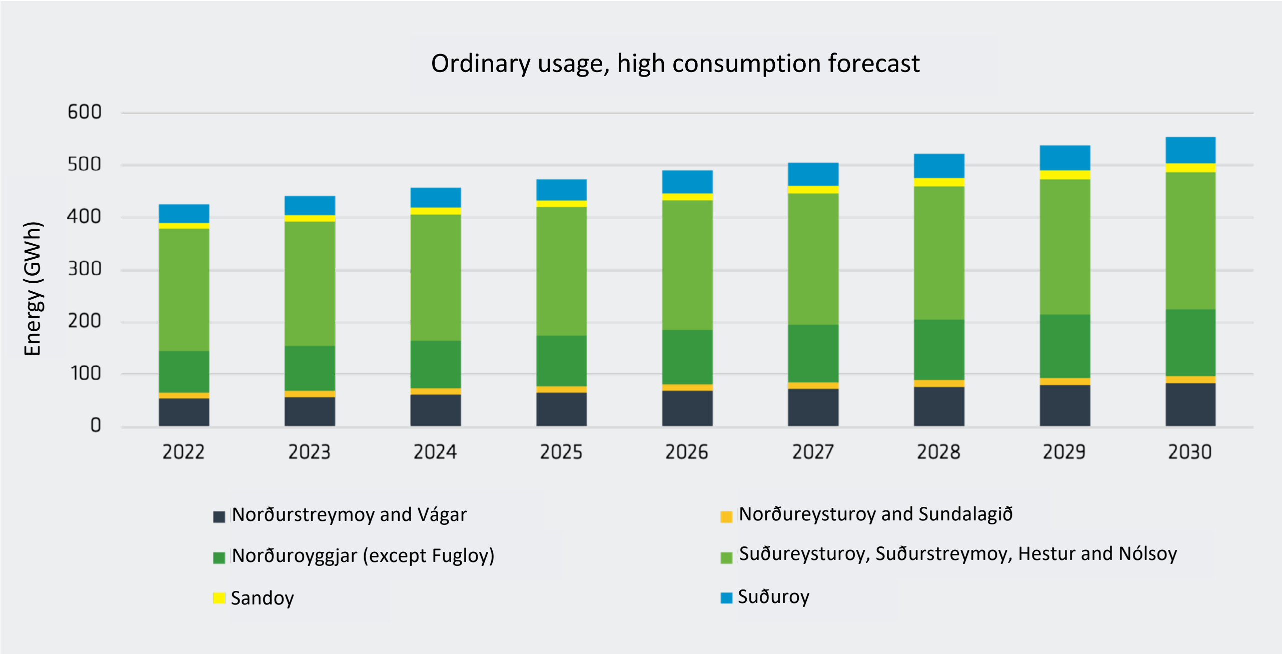


Figure 2 *Ordinary usage, high Consumption Forecast*

3.2 FORECASTED ENERGY CONSUMPTION FOR ONSHORE TRANSPORT

On land an accelerated shift from diesel and petrol cars to electric cars is underway. The basis for these forecasts is statistics from Akstovan (the Faroese Vehicle Administration) and SEV considering:

- Private-use cars on register in the period 2009-2021
- New private-use cars registered the period 2009-2022 (July 1)
- Electric cars on register in the period 2011-2022 (July 1)
- Total electricity usage measured on electric car chargers in the period 2016-2021

These statistics are separated by area. Electric car consumption (electricity usage by chargers divided by the number of electric cars) has hovered between 2.2 and 2.5 MWh per car per annum. Electricity usage was fixed at 2.5 MWh/car in the forecast. This is equivalent to an average driving distance of 15,000 km per year for electric cars. New registered electric cars are distributed by area applying the same ratio as the number of private-use cars per area.

One probable and one high consumption forecast have also been calculated for land transport. Between 2009 and 2021 an average of 6.8% of all registered cars were new cars, the same ratio was applied to the forecast. Of these 6.8% on average 4.4% constituted replacements and 2.4% growth.

Electric car sales are growing exponentially. A projection applying this rate yields that by 2025 all new cars will be electric cars. At this rate 49% of all private-use cars will be electric by 2030.

Probable usage forecast

The probable forecast shown in Figure 3 is based on the calculation that electric car charging usage will rise to approximately 45 GWh by 2030.

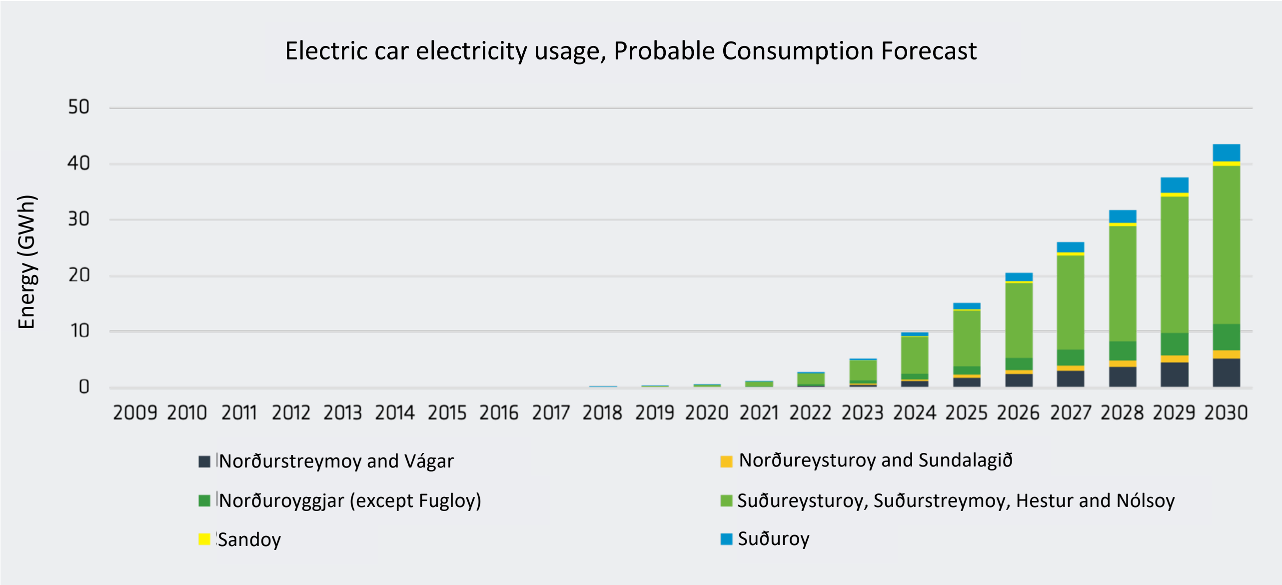


Figure 3 *Electric car charging electricity usage, Probable Consumption Forecast*

High Consumption Forecast

The High Consumption Forecast shown in Figure 4 is calculated based on the assumption that more new private-use cars will be registered (12%), and this will mean that 86% of private-use vehicles will be electric cars by 2030. If this proves to be the rate, then electricity consumption will total approximately 75GWh in 2030.

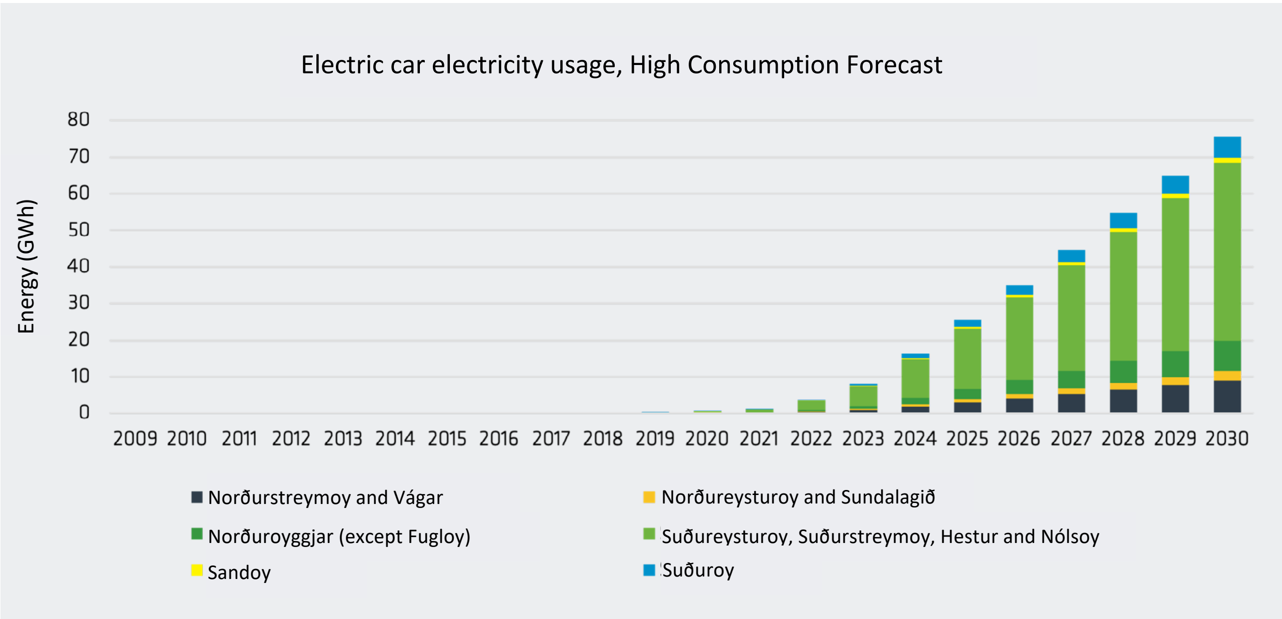


Figure 4 *Electric car charging electricity usage, High Consumption Forecast*

Electric car sales are **growing** exponentially. A projection applying this rate yields that by 2025 all new cars will be **electric cars.**

3.3 HEATING ENERGY CONSUMPTION FORECAST

The energy shift in household and building heating will mainly stem from a transition from oil boilers to heat pumps. The basis for these forecasts is statistics from Statistics Faroe Islands on the number of households in each area in the period 2009-2020. These have been used in conjunction with statistics from the Faroese Environment Agency on the number of ground source heat pump boreholes in each area up to September 16th 2022.

The number of households is growing steadily. From 2009 to 2020 average growth was 1.2%. However, a slight dip was seen both in Suðuroy (-0.001%) and in Sandoy (-0.1%). Growth in Suðuroy was set to 0%, while in Sandoy growth is set as 0.3% because of the Sandoy subsea tunnel. A growth rate of 0.3% is 0.5% to 0.9% lower than in the other areas. The number of households is shown in Figure 5.

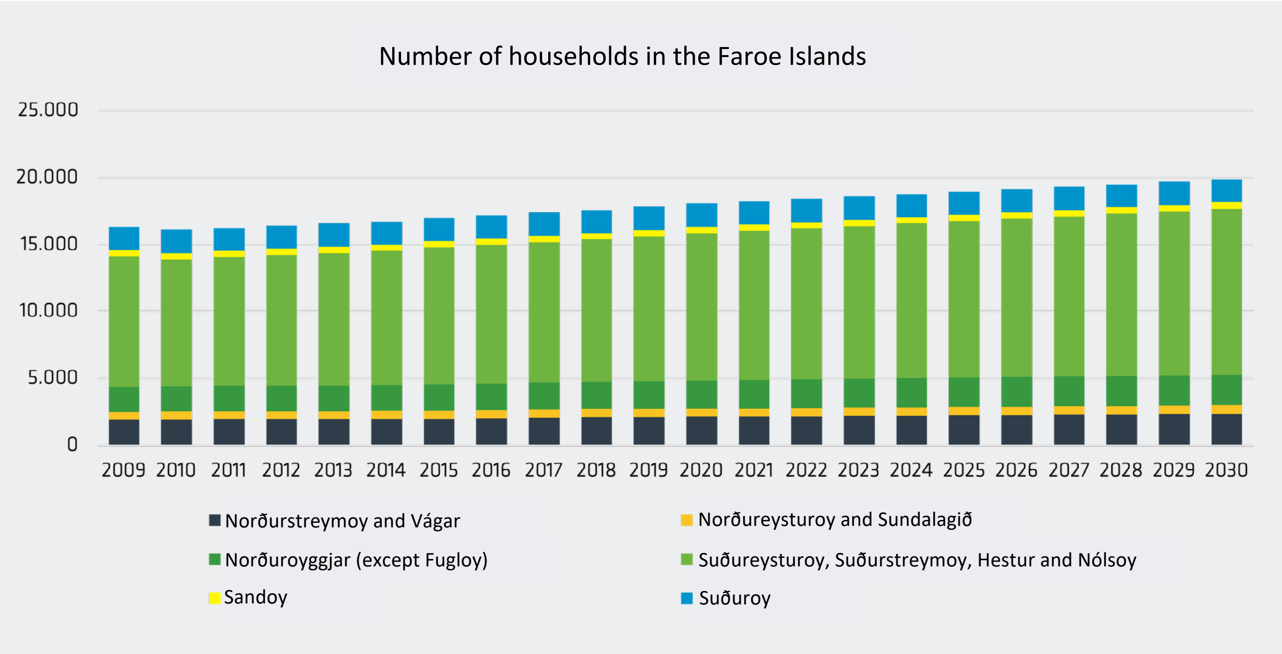


Figure 5 *Number of households in the Faroe Islands*

The Faroe Islands has seen an exponential growth in heat pumps since 2009. At the current growth rate, there will be approximately 9250 pumps by 2030. This would mean that roughly 46% of all households in the Faroe Islands would have a heat pump as main source of heating by 2030.

Heat pump systems consumes 8MWh/year in electric energy, while an additional air to air, heating systems consumes 1.5 MWh/year. In the forecast heat pumps installed in future are distributed by area by applying the same ratio as households per area. For heat pumps already installed, records of ground source heat pump boreholes are used to distribute electricity consumption between the areas.

Probable Consumption Forecast

In the probable consumption forecast, as shown in Figure 6, electricity usage for heating is estimated at approximately 80 GWh by 2030.

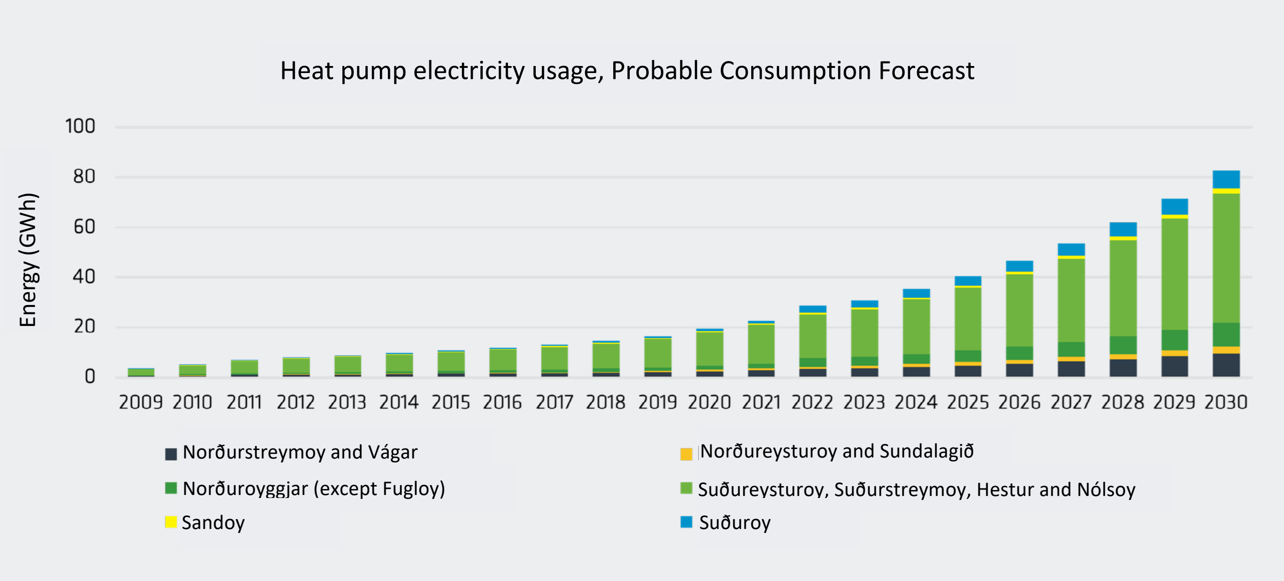


Figure 6 *electricity usage for heating, Probable Consumption Forecast*

High Consumption Forecast

Growth over the last five years has outstripped that of the last 10 years. The high consumption forecast applies the growth seen in the last five years. If this rate is maintained, there will be over 13,000 heat pumps installed by 2030, which is equivalent to roughly 65%.

The high consumption forecast also foresees the installation of 300 new air to air heat pumps per year. This, along with the main heating systems, yields an electricity usage of about 115 GWh, as shown in Figure 7.

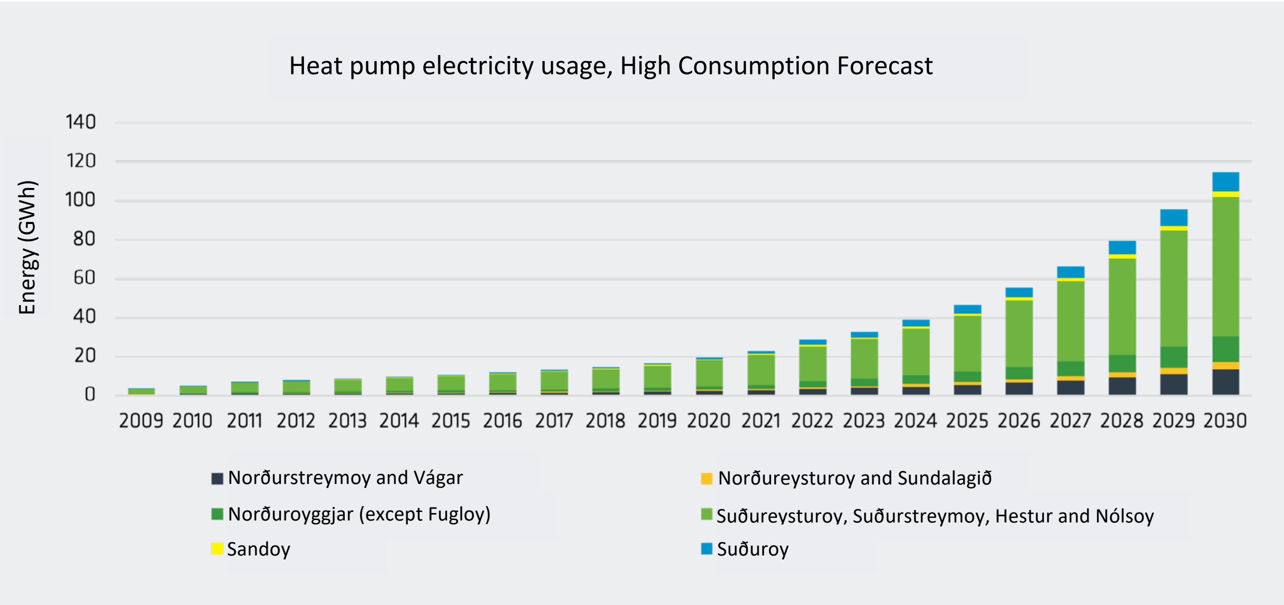


Figure 7 *Electricity used for heating, High Consumption Forecast*

At the current **growth** rate, there will be approximately 9250 pumps by 2030. This would mean that roughly 46% of all households in the Faroe Islands would have a heat pump as main **source of heating** by 2030.

3.4 INDUSTRIAL EXPANSION AND ENERGY SHIFT

Growth in industrial energy consumption in the coming years will stem from expansions or new activity. The basis for forecasting is industrial expansion plans in general, but particularly in onshore aquaculture and the pelagic sector.

Growth calculations are based on industry plans, which were notified to SEV up to and including 2024. Electricity consumption is calculated applying a load factor[1], as well as the duration of the period of the year in which each expansion requires electricity.

In addition, an assessment has been made of the likely energy demand if plants that today use oil for process heating/steam switch to electric energy.

Probable Consumption Forecast

In the probable consumption forecast for industry expansions, as shown in Figure 8, increased electricity usage from new industry activity is estimated at roughly 60 GWh in 2030.

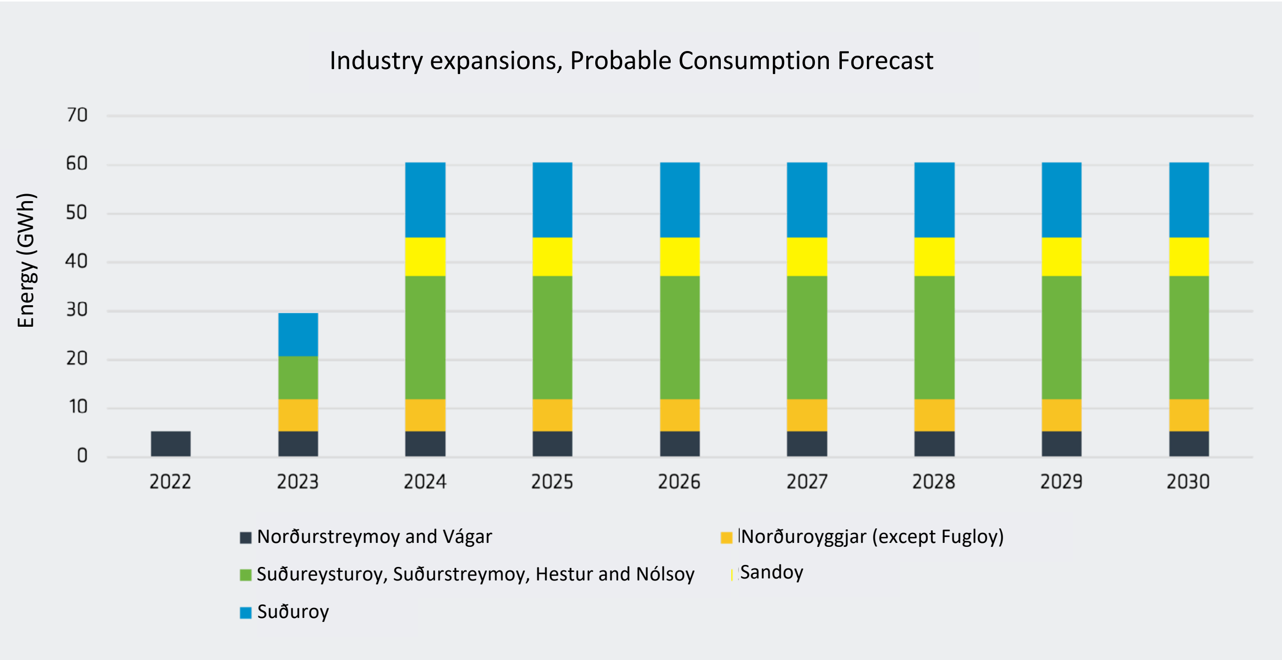


***Figure 8** New industrial electricity usage, Probable Consumption Forecast*

1 A load factor is the average load divided by the highest load

High Consumption Forecast

In the High Consumption Forecast, shown in Figure 9, increased electricity usage from expected new industrial activity may near 100 GWh.

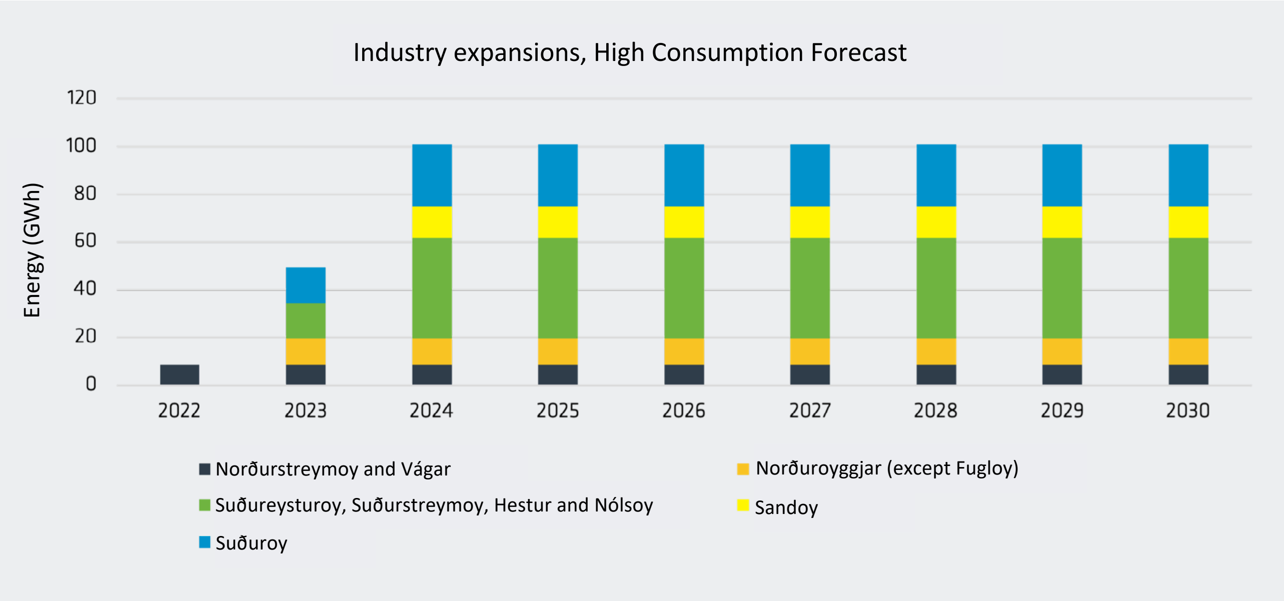


Figure 9 *New electricity usage in industry, High Consumption Forecast*

As mentioned, these projections are based on more or less tangible expansion plans up to approximately 2025. Industry is, of course, likely to continue to expand or build new installations after 2025, so it is not unlikely that usage may be higher than the forecast.

Figure 10 contains one scenario for how electricity demand might grow, if existing plants switch from oil to electricity or, e.g, process, heat, and/or steam. The starting point is a linear transition over the years from 2025 to 2035 and then no change. Once a large proportion of industrial installations have transitioned to electricity, it is estimated that energy demand from these will reach approximately 130 GWh per annum.

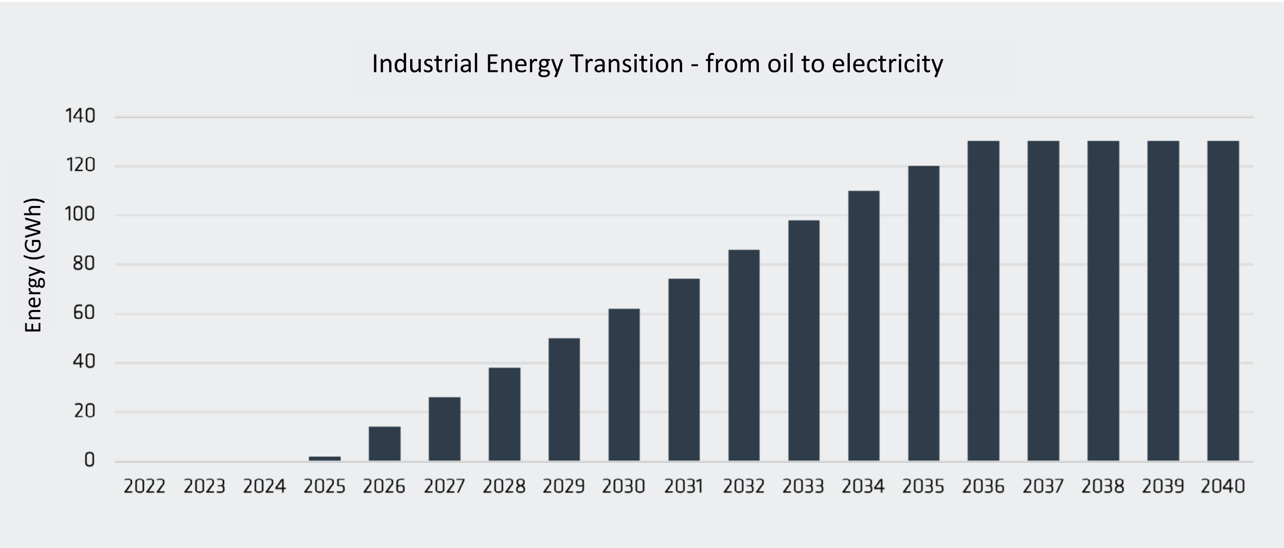


Figure 10 *Energy demand considering an energy transition in existing industrial installations*

3.5 MARITIME ENERGY TRANSITION

The working party has assessed the potential rise in electricity demand, if the Faroese fleet transitions from oil to a green fuel, such as ammonia or methanol, produced in the Faroe Islands, using green electricity.

There are several options for green fuel production. At present, it is unclear what type of fuel it would be. However, it would appear that one common denominator for these green fuels is green hydrogen (H_2) produced using electrolysis powered by renewable energy sources.

The basis for these projections is a shift from oil to ammonia (NH_3). Green ammonia can be produced from green hydrogen (H_2) and nitrogen (N_2). The simple reason for this choice is the feasibility of producing green ammonia in the Faroe Islands, given that the raw materials are available here.

One of the disadvantages of green fuel production is that the total energy conversion efficiency is very low. The total energy conversion efficiency when producing hydrogen using electrolysis, then producing ammonia using the hydrogen, and subsequently burning the ammonia in a combustion engine is estimated at only about 20%.

However, hydrogen and ammonia production do offer several interesting synergies, for example, surplus heat, which can be fed into a district heating grid as well as oxygen (O_2), which is used in aquaculture.

Given the margin of uncertainty when discussing a future maritime energy transition, only one consumption forecast has been calculated. The projection is based on the assumption that a cautious transition will begin in 2026, and that roughly half of the maritime energy demand, which today is met by oil, has shifted to ammonia by 2040.

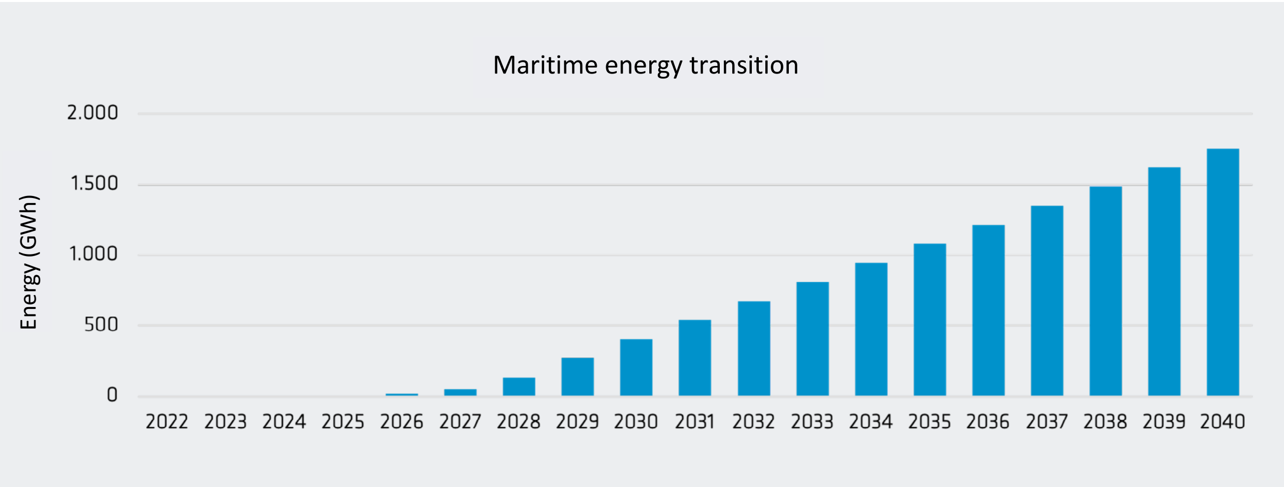


Figure 11 *Energy Consumption given a maritime energy transition*

Not unexpectedly, it becomes clear from Figure 11 that in spite of a cautious beginning in 2026, a maritime energy transition is highly energy intensive. Given the preconditions assumed and outlined above, the electricity demand for the production of green ship and boat fuel is estimated at approximately 400 GWh by 2030, and approximately 1.7 TWh (1700 GWh) by 2040.

3.6 TOTAL ENERGY CONSUMPTION FORECAST 2022-2040 WITHOUT INDUSTRIAL OR MARITIME ENERGY TRANSITIONS

Based on the various projections above, we can estimate the total energy demand. Two consumption forecasts are considered, one probable, and one high. In addition, consumption forecasts have also been calculated taking into account a shift in consumption by onshore industry from oil to electricity and a maritime transition from oil to a green fuel, which in these forecasts is ammonia.

Probable consumption forecast

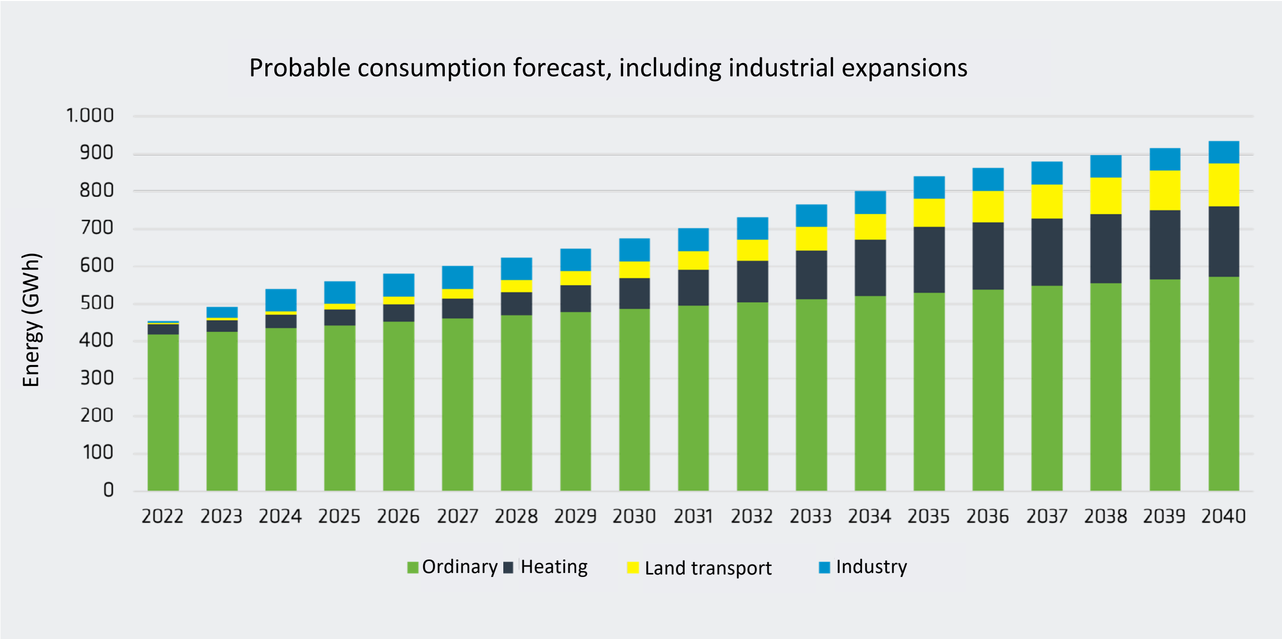


Figure 12 *Probable consumption forecast - including industrial expansions*

Figure 12 shows the Probable Consumption Forecast not taking into account industrial or maritime energy transitions. In this consumption forecast energy demand by 2030 is estimated at 675 GWh and approximately 935 GWh by 2040.

High consumption forecast

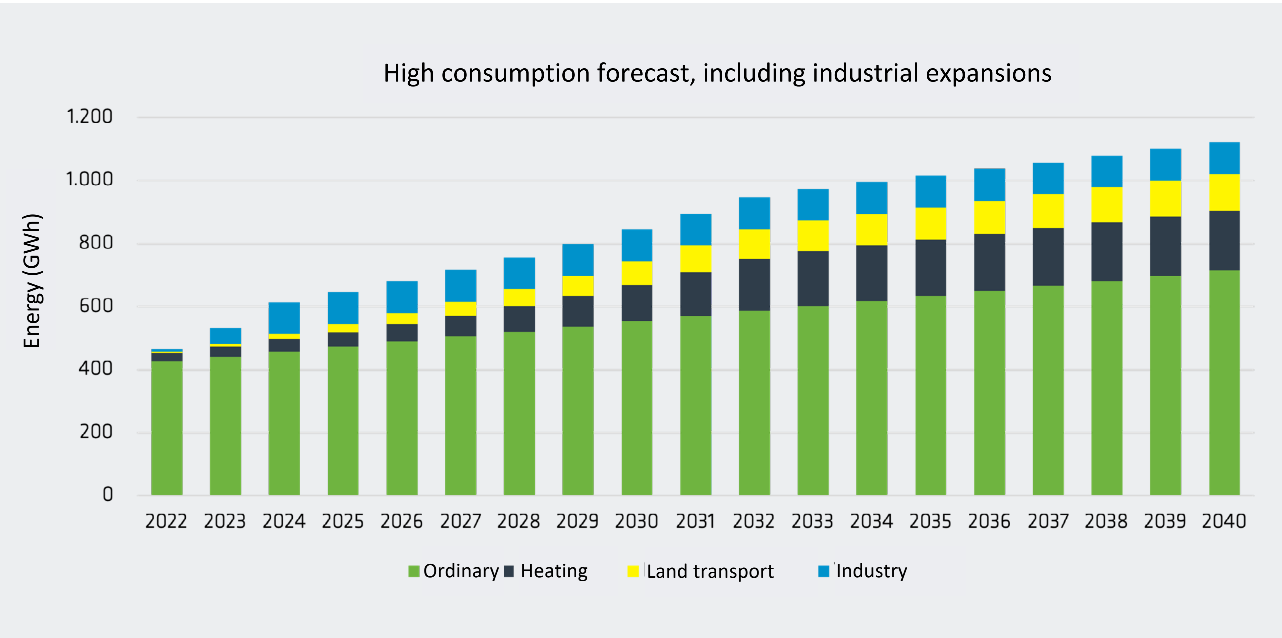


Figure 13 *High consumption forecast - including industry expansions*

The High Consumption Forecast, as shown in Figure 13, does not take into account an industrial or maritime energy transition. Energy demand by 2030 is estimated at 845 GWh rising to approximately 1,125 GWh by 2040.

Both these forecasts, shown in Figure 12 and in Figure 13, take into account ordinary electricity, usage, electricity used for heating and land transport. In addition, expansions and new activities in the industrial sector have been used as a basis for the expansion schedule up to 2030.

3.7 FORECASTED ENERGY CONSUMPTION, INCLUDING INDUSTRIAL AND MARITIME ENERGY TRANSITIONS

If the forecast takes into account an energy transition from oil to electricity among existing onshore industry, as well as a maritime energy transition applying the assumption that half of all ships and boats will be burning a green fuel by 2040, and that this fuel will be ammonia, the forecast sees a considerable rise in energy demand in particular from the energy intensive maritime transition.

Probable consumption forecast

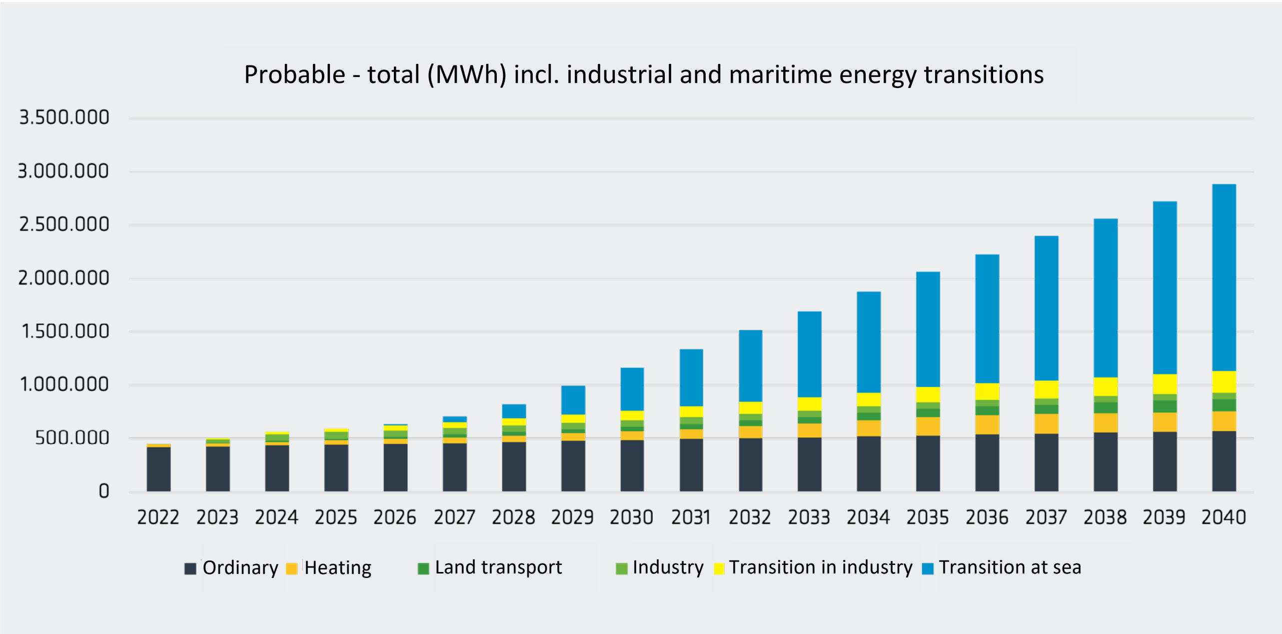


Figure 14 *Probable Consumption Forecast - including industrial and maritime energy transitions*

In the Probable Consumption Forecast, seen in Figure 14, the total energy demand by 2030 is estimated at roughly 1,170 GWh rising to approximately 2,890 GWh by 2040. This forecast factors in the maritime and onshore industrial energy transition.

High consumption forecast

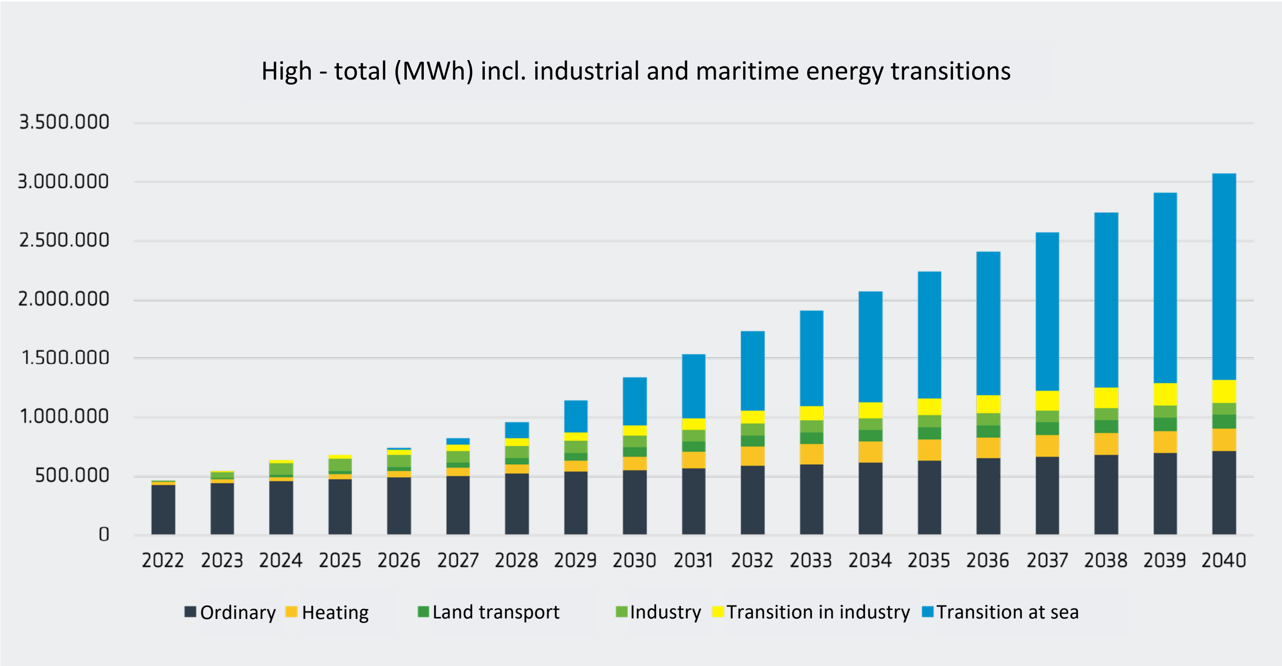


Figure 15 *High consumption forecast - including industrial and maritime energy transitions*

Figure 15 shows the consumption forecast at the highest energy demand. This forecast presupposes an energy transition among existing onshore industrial facilities, as well as a maritime energy transition. This consumption forecast estimates that the demand for energy will approach 1,340 GWh by 2030 rising to about 3080 GWh by 2040. It is worth noting that maritime energy demand represents over half of the total energy demand, even though the assumption in this projection is that only half of ships and boats will have switched fuels by 2040.

If by 2040 all maritime energy consumption has shifted to ammonia produced in the Faroe Islands, then the total electricity demand will approach 4,600 GWh per year.

If by 2040 all maritime **energy consumption** has shifted to ammonia produced in the Faroe Islands, then the total **electricity** demand will approach 3,500 GWh per year.

4. Expansion schedule up to 2030

4.1 WIND POWER EXPANSION SCHEDULE

Based on the model calculations, refer to ‘Expansion Schedule, Model Calculations’, Table 1 shows the wind power expansion schedule up to 2030.

Type	Placement	Island	Output	Tender	Operation	
Wind power	Porkeri	Suðuroy	6 MW	2024	Q3/2025	20 kV
	Klivaløkshagi	Sandoy	20–30 MW	2023–2024	Q3/2025	20 kV
	Glyvrafjall*	Eysturoy	25 MW	2025	Q3/2027	60kV
	Junkarahagi*	Streymoy	21 MW	2027	Q3/2029	20 kV
	Vestfelli*	Sandoy	50 MW	2029	Q3/2030	60kV
	Total wind power expansion		**136 MW**			
	*Further studies are required to determine suitable locations, environmental impact, etc.					

Table 1 *Wind Power Expansion Schedule*

In addition, there is also an expansion schedule for Eiði where SEV in 2019 won the right to install 18 MW of wind power. The programme hit a snag and was reduced to 4 wind turbines and has since been put on hold. Should this project be resumed, one option may be to install four or five large turbines at short notice, which can produce a total of approximately 18 MW.

As regards the wind power expansion in Klivaløkshaga wind speed studies have been carried out, which have determent that the area is ideal for wind power production. One precondition for this project is the installation of a 60 kV connection in Sandoy and the construction of a substation.

In Porkeri there are wind turbines at present and it is likely that additional turbines can be installed there. Simulations show that 6 MW need to be installed in Suðuroy, however, it should be noted that Varðin Pelagic’s plan for a new protein plant in Tvøroyri is not included in the projections. The construction of such a plant would nearly double energy demand in Suðuroy and would require amending the general expansion schedule somewhat.

The results from the optimisation clearly show that nearly half of production from the expansion in Porkeri has been down regulated, and a large proportion of the other half is exported to the central area via cables, which the model also chooses to invest in. It is not a stretch to think that investing in more wind power in the central area would be as, or perhaps even more, cost-effective, however, given that the options for installing more wind turbines in the central area are very restricted in 2024, the model makes investments in Suðuroy, in order to ensure compliance with the CO_2 emissions reduction requirement.

One factor that does, however, support expanding wind power in Suðuroy is that the expansion schedule foresees 20 MW less of solar power than the optimisation arrives at. This means that the proportion of the energy production that was previously exported to the central area will be used in Suðuroy.

Glyvrafjall, Junkarahagi and Vestfelli are suitable locations for wind power generations, but further wind speed measurements and impact studies are required in these areas. A measuring mast has been installed in Glyvrafjall and wind measuring masts are due to be installed in Junkarahagi and Vestfelli in 2023/2024.

It is hardly a technical challenge to install 50 MW in Vestfelli, compared to the total wind power in the area west of Tórshavn (Flatnahagi, Húsahagi and Hoyvíkshagi), which totals 55 MW, as well as the necessary stabilising equipment required in this context. With large-scale wind power production in Sandoy and a cable between Suðuroy and Sandoy, Sandoy becomes an energy hub where energy is both produced and transferred between the larger areas in the Faroe Islands.

One interesting alternative area, which should be studied more closely, is Kirkjubøreyn , which is deemed to be especially well-suited to wind power generation.

Plans for a potential airport in Glyvursnes have so far prevented the installation of a wind speed measuring mast there. The feasibility of these plans for an airport in Glyvursnes should be clarified, so that this area could, alternatively, be used for wind power.

One approach that could attract more investors and generate advantages of economy of scale would be to group the tenders listed in the expansion schedule in Table 1. This could be done by launching a single tender for a series of wind farms with a schedule stipulating when each individual wind farm should enter operation. This would mean offering a combined tender of approximately 130 MW, which is equivalent to an investment of roughly DKK 0.9 to 1 billion.

The working party recommends making targeted efforts to make Kirkjubøreyn available for wind power generation.

The working party recommends taking a closer look at different approaches to tendering wind power, which could increase interest in taking part in the tender, as well as in the operation of wind farms, e. g. by grouping a series of wind farms in one tender with specific conditions for when and where each wind farm is to be installed.

4.2 SOLAR POWER EXPANSION SCHEDULE

Solar power systems have been generating power in the Faroe Islands for the last five years offering a good steady yield, see Figure 16.

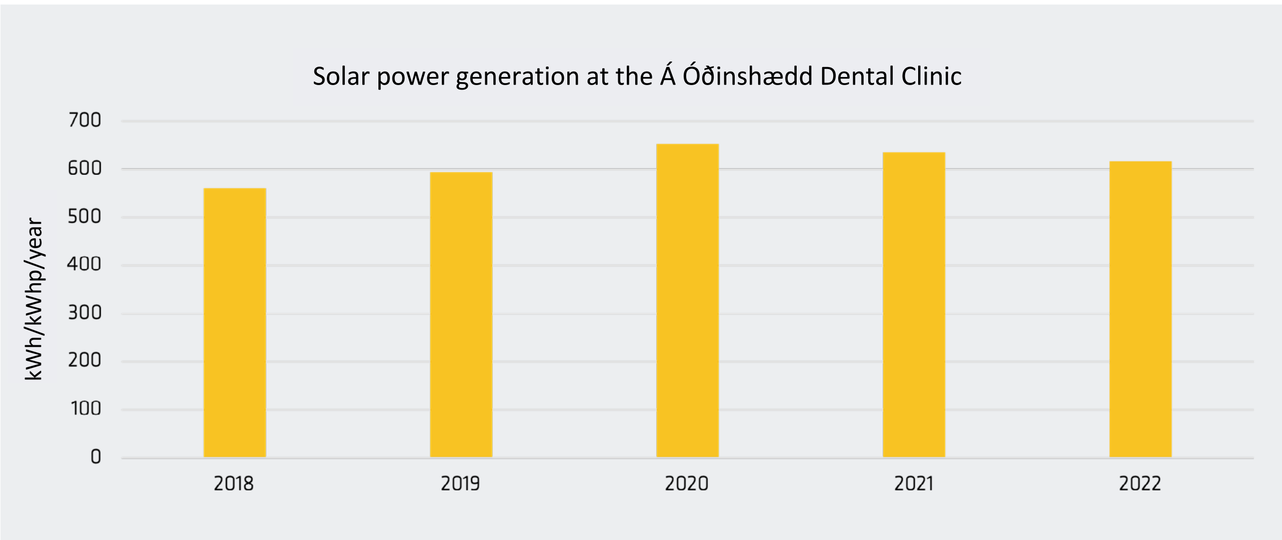


Figure 16 *Solar power generation in Tórshavn*

Solar power will play a significant role in the future energy system, because it is mostly generated during the summer when wind and water power generation dips, and also because solar power can compete with other solutions as per studies carried out. This is especially true in an electricity generation system, which does not permit CO_2 emissions. In this case, solar power contributes to reducing the need for large energy stores. Table 2 shows that solar power systems will be required throughout the country.

Such installations could be achieved through organised tenders, but also by encouraging the placement of large and small solar power installations on rooftops and larger buildings.

The optimal financial results for solar power expansions demonstrate that a large proportion should be installed already in 2024. The reason for this is, as shown in 'Expansion Schedule, Model Calculations', restricted investment opportunities in other technology in 2024, which could contribute to reducing CO_2 emissions.

If the *100% green* approach is compared to the other two approaches, *95% green* and CO_2 permitted, it is clear that there are significantly fewer expansions in the *95% green* approach and that no solar power is included in the CO_2 permitted approach. A more cautious solar power expansion has therefore been selected. It contemplates 5 MW/year from 2024 to 2026 followed by 10 MW/year from 2027 to 2030. In principle, solar power would be installed in the areas recommended in the optimisation.

Simulations with 88 MW of solar power, reduce unmet demand by 1% of total generation. Higher solar power generation leads to higher downscaling of wind power.

Year	Area 1	Area 2	Area 4	Area 5	Area 6	Area 7	Total
	Norðurstreymoy and Vágar	Norðureysturoy and Sundalagið	Norðoyggjar	Suðureysturoy, Suðurstreymoy, Hestur and Nólsoy	Sandoy	Suðuroy	
2024			1 MW	2 MW	1 MW	1 MW	5 MW
2025			1 MW	2 MW	1 MW	1 MW	5 MW
2026			1 MW	2 MW	1 MW	1 MW	5 MW
2027		1 MW	3 MW	3 MW	1 MW	2 MW	10 MW
2028			3 MW	3 MW	2 MW	2 MW	10 MW
2029	8 MW	2 MW					10 MW
2030	5 MW	3 MW		2 MW			10 MW

Table 2 *Concrete solar power expansion schedule*

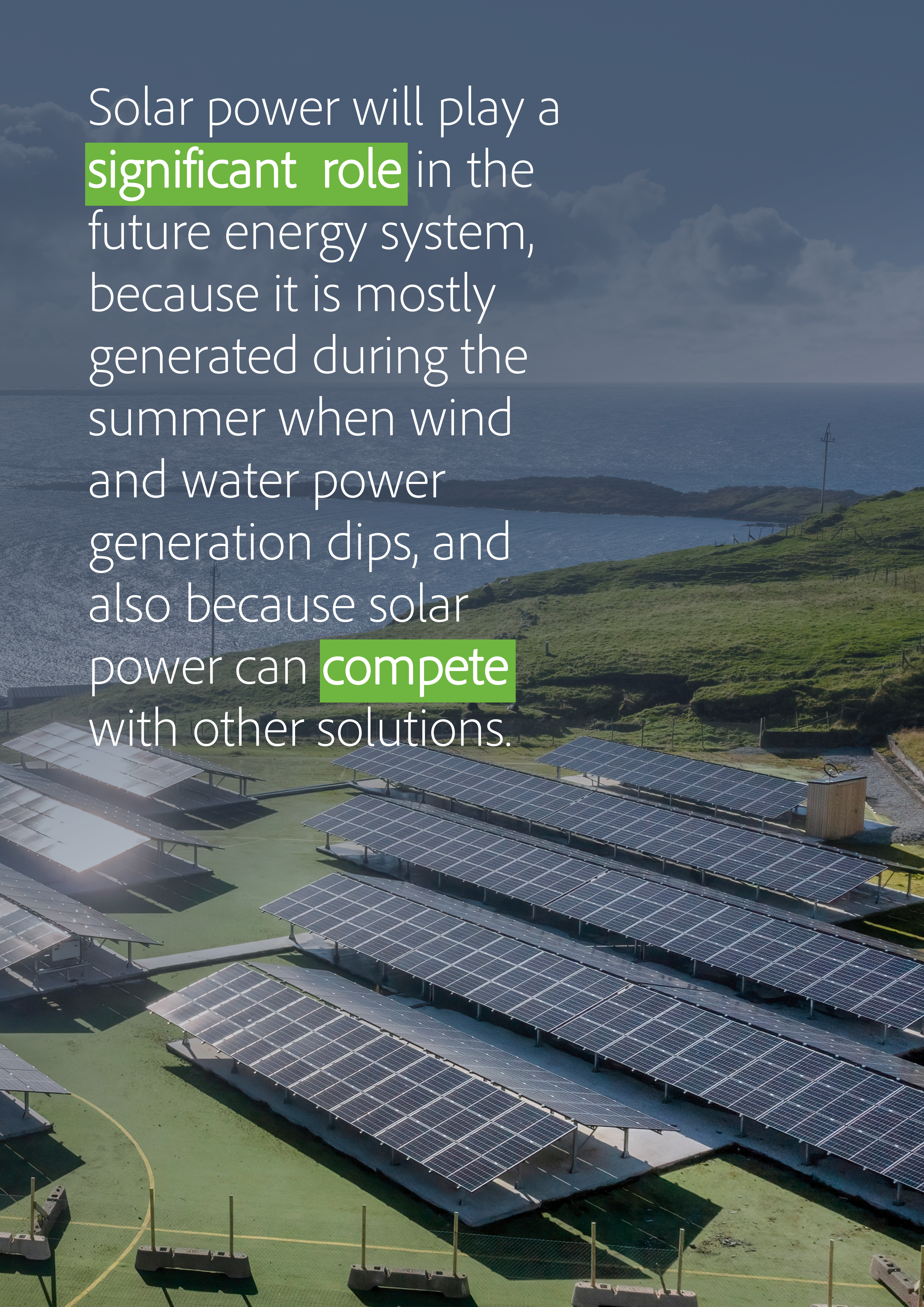
One approach to a tendering solar power could be to launch a public tender for 5MW in 2024. This tender could be divided into smaller solar power plants without any conditions regarding size or placement. This would allow interested parties to enter bids, which the grid operator and authority would review jointly in terms of placement, connection to the grid and economic considerations.

This tendering approach would allow for flexibility in relation to placement, which could be on suitable land, large industrial buildings, or potentially as floating solar plants on lakes.

Given that this would be the first tender of its kind in the Faroe Islands, the approach should be reviewed following the first tender and any necessary amendments should be made before launching any subsequent tender. The working party recommends tendering the first 5MW of solar power in 2024.

In order to increase interest among potential tenderers, the working party recommends examining various approaches to tendering solar power.

Solar power will play a **significant role** in the future energy system, because it is mostly generated during the summer when wind and water power generation dips, and also because solar power can **compete** with other solutions.



4.3 BATTERY EXPANSION SCHEDULE

SEV hevur ítøkiliga ætlan um, hvussu battarískipanir skulu byggjast út komandi árini⍰ Høvuðsendamálið við hesum battarískipanum er at tryggja støðufestið í elskipanini, tá útbygt verður við óstøðugum orkukeldum⍰

Val av battarískipanum, uppsetingarár, stað, stødd í mátti og orkugoymslu sæst í Talvu 3⍰

Year	Placement	Output (MW)	Energy storage (MWh)
2023	Sund	12	12
2024	Skálabotnur	25	25
2025	Sandoy	15	15

Table 3 *Battery systems*

The battery system in Sund is already installed and will become operational shortly. Batteries have a special role in stabilising electric power from wind farms and solar plants, but also as energy stores for periods shorter than one hour. This is why they are distributed across the power grid and why they will be installed in the near future. As of 2028, the need for batteries as energy stores will have dropped slightly, because at that point the pumped hydro system in Vestmanna will begin operation and a pumped hydro system has some of the same characteristics as batteries, as well as enabling a much larger energy storage.

4.4 CABLE TO SUÐUROY

The plan is to connect Suðuroy to the central area via a 60 kV cable connection between Sandoy and Suðuroy, see Figure 17. This interconnection will make the grid larger and more robust overall and will also allow for taking advantage of staggered energy production and energy usage in both areas. The cable would also enable expansions with renewable energy sources in Suðuroy, which could also benefit the central area.

A cable connection between Suðuroy and the central area will reduce the need to expand total dispatchable power. Given that electricity usage in Suðuroy is largely linked to industry, which is partially delayed in relation to the electricity usage in the central area, and a cable would probably reduce the overall need for expansion of dispatchable power.

In the simulations, refer to 'Expansion Schedule, Model Calculations', the model has the option to invest in a subsea cable between Sandoy and Suðuroy. The model chooses to make this investment in 2024, and then increases power again in 2030. In the expansion schedule, however, the cable is scheduled for 2026. This owes to logistical considerations such as supply times, processing licenses, etc.

Another consideration in relation to a cable between Sandoy and Suðuroy is whether a subsea tunnel is built or not. A cable placed inside a subsea tunnel is much cheaper and lasts considerably longer than a subsea cable.

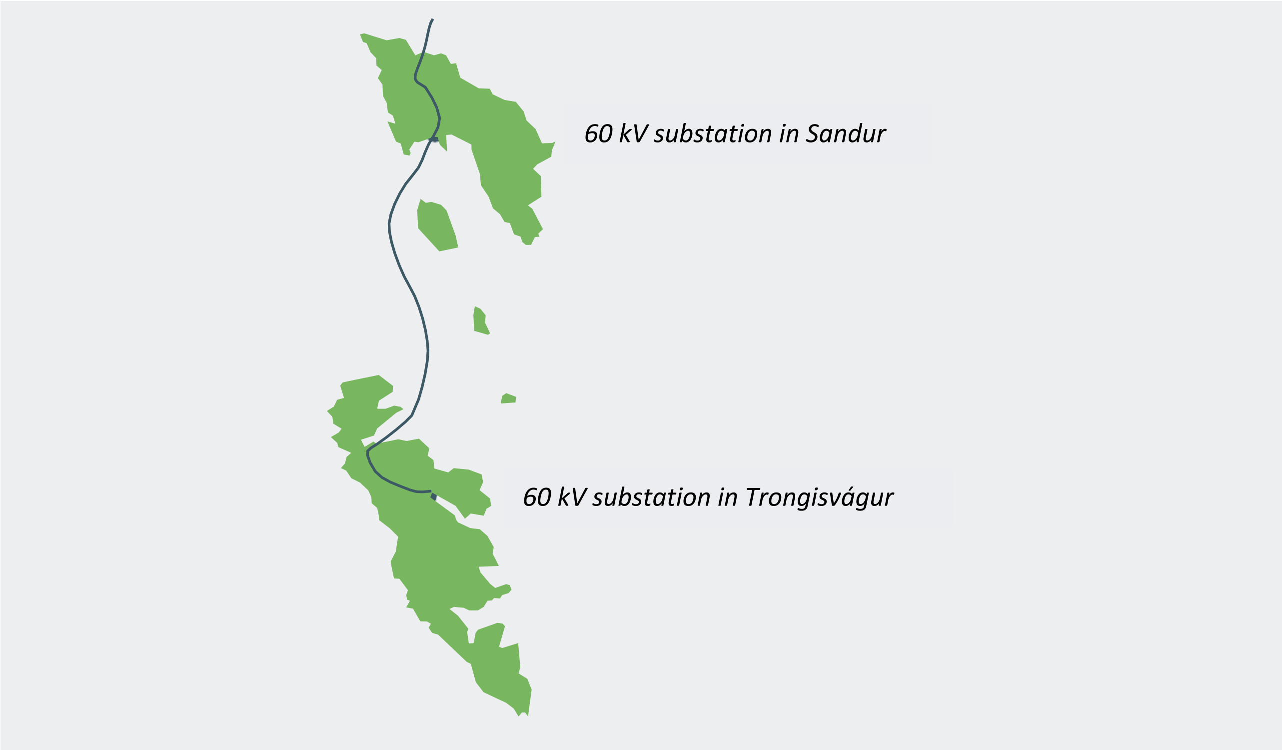


Figure 17 *60 kV subsea cable between Sandoy and Suðuroy*

4.5 PUMPED HYDRO STORAGE IN VESTMANNA

There are several sources of renewable energy in the Faroe Islands, but most are weather dependent. Several studies and reports have indicated that expanding wind power is the most cost effective solution, however, the changing weather and seasons mean that there will be periods, perhaps particularly in summer, where power generation will be insufficient to meet demand, and other periods, particularly in winter, where power generation will largely exceed demand. The report 'Energy stores in the Faroe Islands' from 2018 concluded that there is a need for a pumped hydro system that would enable the storage of surplus electricity in a dam, which could subsequently generate green hydroelectricity to be added to the grid.

In 2022 a provisional license was granted to build the pumped hydro system between the dams in Heygadalur and á Mýrunum in Vestmanna. The pump capacity is 70 MW and the turbines can produce 40 MW. The total cost is estimated DKK 1.3 billion.

In order to limit the environmental impact of such a system, the pumped hydro system is under construction inside the mountain, so that only one entrance to the plant hall is visible in the landscape.

Figure 18 *Portal to the pump system in Heygadalur*

The dams will not be raised initially, but there is an option to raise the dams somewhat if it proves necessary at a later stage. It can be mentioned that if, for example, tidal energy and solar power, over time come to play a larger role in the Faroese electricity system, or some form of green fuel, this will significantly limit the need to raise the dams. The reason for this is that tidal energy is predictable and not weather dependent the way wind or hydropower are. Solar power is a largely available in summer when little wind or rain is available.

The pumped hydro system in Vestmanna could increase the proportion of renewable energy by 7 to 10% and reduce emissions by roughly 35,000 tonnes of CO_2 per year. In addition, the pumped hydro system has characteristics that are crucial for sustaining the system, such as inertia, and short-circuit effect, and it also constitutes a decisive precondition for the installation of significantly more wind and solar power over the coming years.

4.6 GENERATION ACCORDING TO THE EXPANSION SCHEDULE

Once the expansion schedule was drawn up taking into account financial, technical and practical factors, a new simulation was carried out, which was intended to demonstrate the energy mix and the financial difference between the optimal plan (100% green), refer to 'Expansion Schedule, Model Calculations', and this adapted and more tangible expansion schedule.

Figure 19 shows the energy mix when applying the tangible expansion schedule. The figure shows, among other things, that generation by 2030 is 92% green energy based.

It is also clear from Figure 19 that some years will see a shortfall in green energy (*'unmet demand'*) in order to comply with the set requirement of a strict linear reduction in CO_2 emissions towards 2030. It means that 2030 will see an energy shortfall of approximately 59 GWh, i.e. 8 percentage points short of 100% green energy. If these 59 GWh could be produced using a CO_2 neutral fuel by 2030, for example at the Sund power plant, then total production could become 100% green by 2030.

In the *100% green* approach, refer to 'Expansion Schedule, Model Calculations', there is no 'unmet demand', and this means that that approach is 8 percentage points greener than the approach using the tangible expansion schedule. The financial implication of this is indicated in the next paragraph.

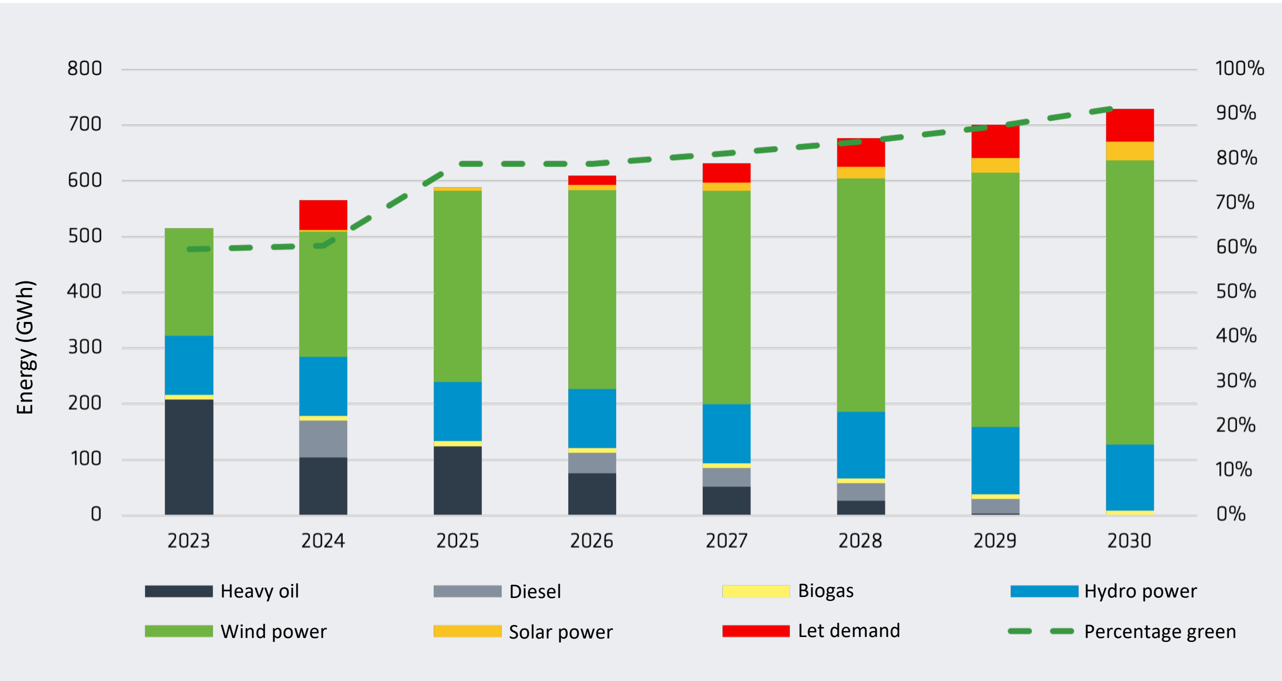
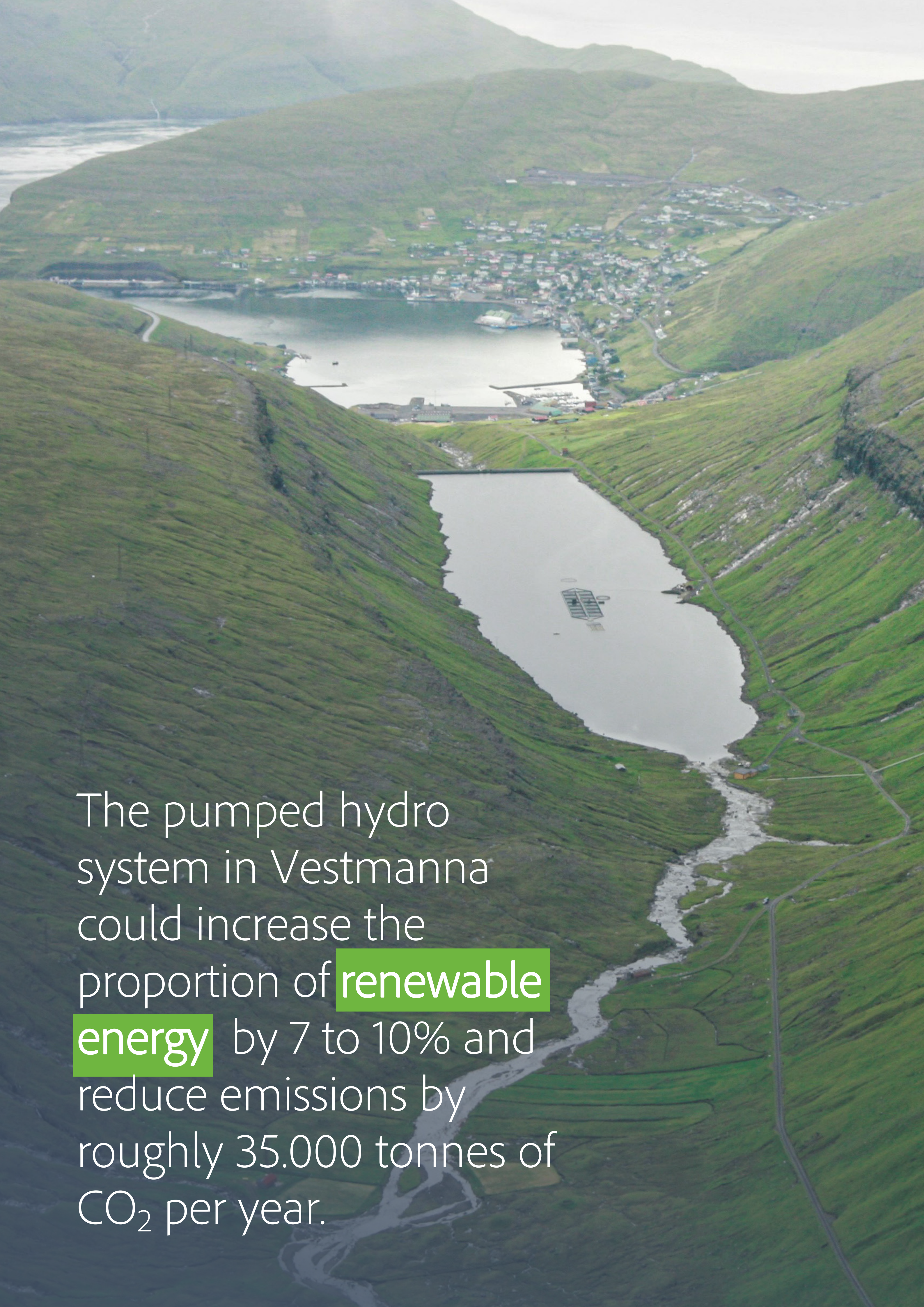


Figure 19 *Expansion schedule energy mix*



The pumped hydro system in Vestmanna could increase the proportion of renewable energy by 7 to 10% and reduce emissions by roughly 35.000 tonnes of CO_2 per year.

4.7 FINANCES

Figure 20 shows the annual investments in production, storage and grid for the expansion schedule and the 100% green approach.

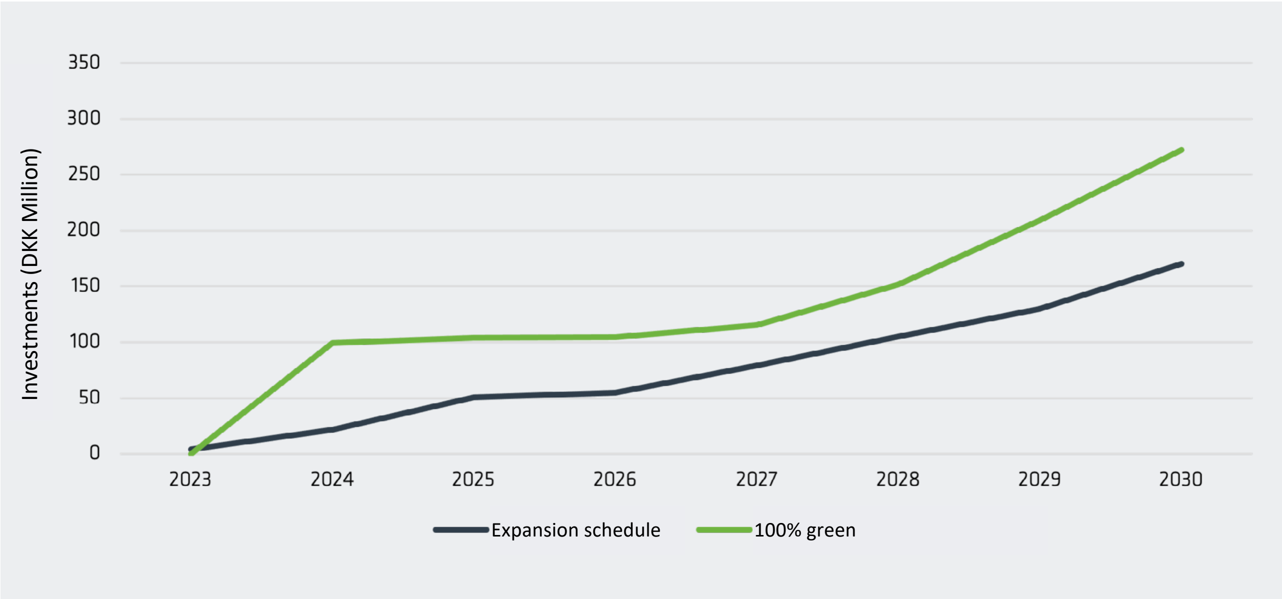


Figure 20 *Annual investment costs 2023 - 2030*

As previously mentioned, the expansion schedule is 8 percentage points less green than the *100% green* approach. However, as indicated in Figure 20, the total annual investments in the expansion schedule are lower than the total annual investments in the *100% green* approach. Looking at the period 2023 to 2030, the difference is approximately DKK 440 million.

Figure 21 shows the annual operating costs of the expansion schedule and the *100% green* approach. It shows that the total operating costs are slightly higher for the expansion schedule, and considering the period 2023 to 2030 the difference is approximately DKK 210 million where a large proportion of the difference stems from fuel costs under the expansion schedule used to satisfy unmet demand, which would have to be covered using oil or potentially other green fuels at the Sund Plant.

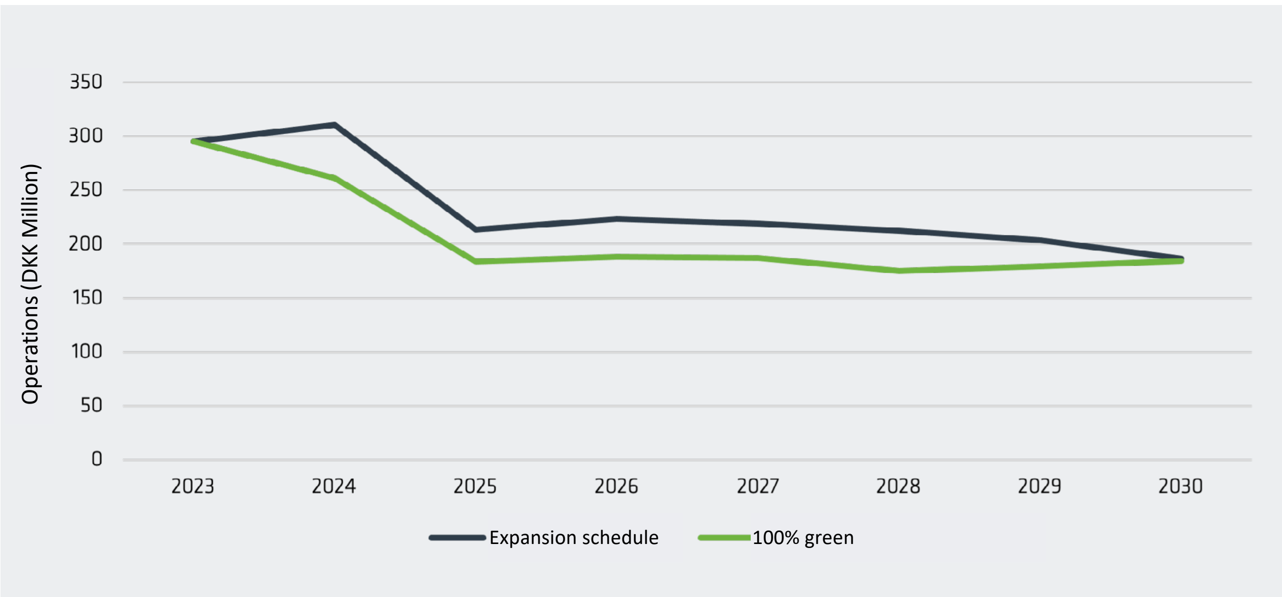


Figure 21 *Annual operating costs 2023 to 2030*

4.8 CO_2 EMISSIONS REDUCTION

Figure 22 shows the gradual reduction in CO_2 omissions from electricity generation up to 2030, in line with the expansion of sustainable energy production.

It too shows a shortfall in green energy (unmet demand) in order to reach the set target of a strict linear reduction in CO_2 emissions by 2030. Based on the assumption that this unmet energy demand is satisfied through oil-based generation at the Sund Plant, CO_2 emissions will total approximately 27,000 tonnes in 2030. However, if the energy shortfall is covered by generation using a green fuel, CO_2 emissions will be near zero.

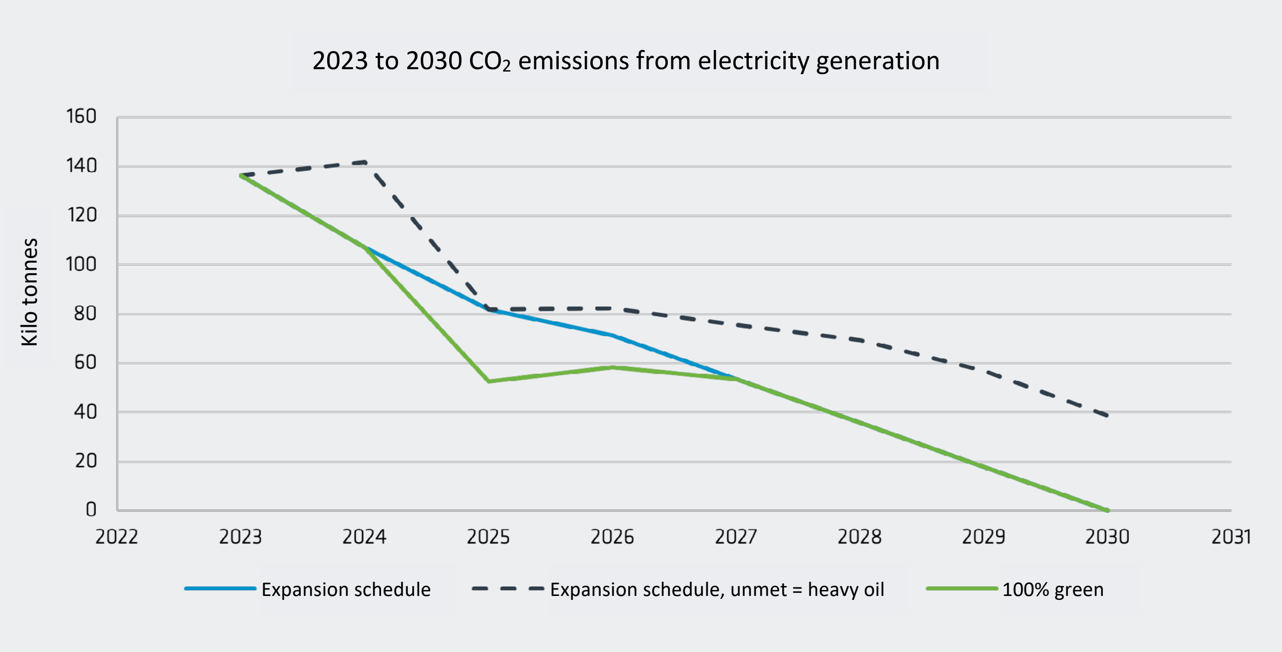


Figure 22 *2023 to 2030 CO_2 emissions applying the 100% green and expansion schedule approaches*

As mentioned, two forecasts were made one ‘Probable’ and one ‘High’. Table 4 shows a rough estimate of the potential reduction in oil consumption when applying the probable forecast to the various consumption categories.

By 2030 emissions from 172,000 tonnes of oil will equal roughly 550,000 tonnes of CO_2. This is **45%** lower than in 2010.

If SEV’s fuel becomes CO_2 neutral, emissions will be 40,000 tonnes lower or 510,000 tonnes, which would be **49%** below 2010 levels.

	2022 (tonnes)	**2030 (tonnes)**
Consumption category	**Oil consumption**	**’Probable’ oil consumption**
Land transport	35,000	17,850
Heating buildings	45,000	15,750
Land-based industry*	25,760	16,000
Maritime*	144,200	110,000
SEV	43,588	12,500
Total	295,000	172,100

** not included in the simulations*

Table 4 *Oil consumption divided into consumption categories*

4.9 SURPLUS ENERGY

Even if expansions were to take place, according to the most cost-effective schedule or the adapted expansion schedule, (refer to 'Expansion Schedule, Model Calculations'), and a pumped hydro system were also operational by 2028, there would be a certain volume of wind power, which could not be fed into the grid as it becomes available, here termed surplus energy. This might happen during hours or days when sustainable energy production outstrips energy usage.

Based on the expansion schedule, as shown in Table 1, there will be, according to the Balmorel simulations, an annual average surplus energy of around 70 GWh during the initial period (2023 to 2028). After this, in 2029 and 2030, the model makes fairly large investments in wind power in order to ensure compliance with the strict CO_2 emissions reductions targets. The consequence is that only part of production can be distributed via the grid, which means that surplus energy becomes fairly high in these years. Figured 23 below shows a forecast for potential surplus energy up to 2030.

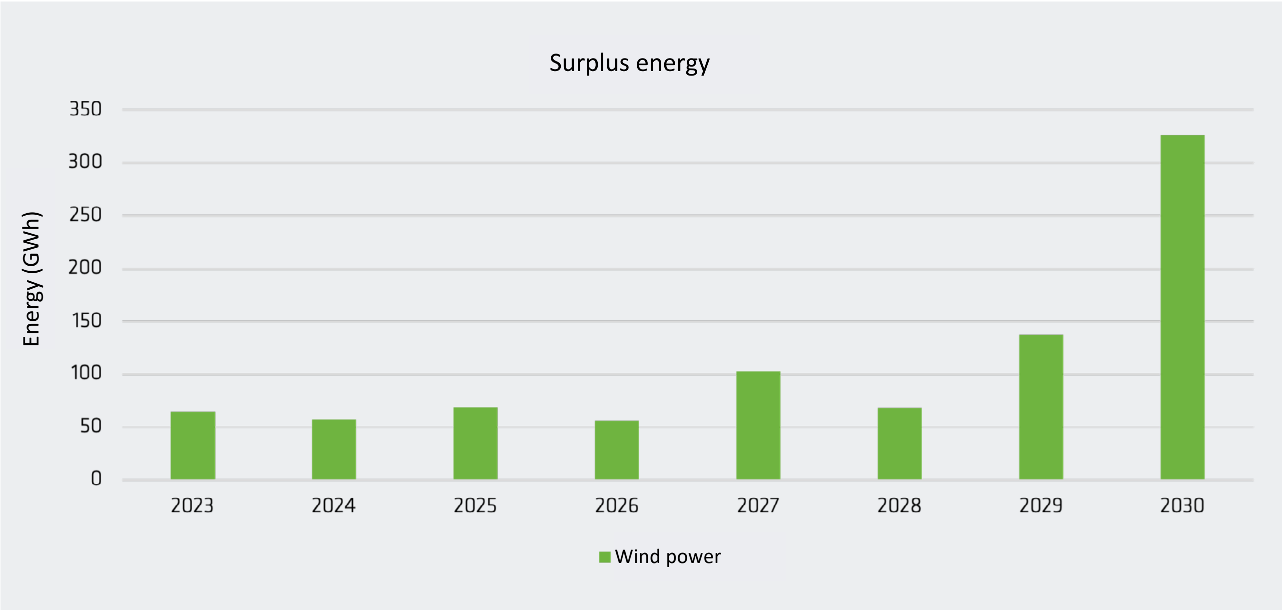


Figure 23 *Potential surplus energy 2023 to 2030*

The challenge of surplus energy is that it is impossible to predict with certainty when it will be available. From a socioeconomic perspective any potential surplus energy should, to the greatest extent possible, be harnessed for a good purpose, where energy demand is flexible and can be staggered over time. Another suggestion would be to store surplus energy perhaps as heat, as hydrogen, or by other means.

Alternatively, surplus energy, with its limitations, could support industrial activity that today runs on oil. One example might be process heat where heat today is generated from oil. Here surplus energy could be used when available, both directly or stored in a heat stores, thereby reducing oil consumption.

5. Future electricity requirement (2030 - 2040)

The industrial energy transition, both on land and at sea, is a major challenge. Onshore it must take account of new activity, such as expansions in the pelagic industry and aquaculture industry, as well as the energy transition of existing plants shifting from oil to electricity. The maritime energy transition is likely to be a shift from oil to some form of green fuel. If this fuel is to be produced in the Faroe Islands, it will place immense pressure on expansion of renewable energy in the coming years.

An energy transition in onshore industry would mean an increased electricity demand of about 150 to 200 GWh by 2040, and the energy requirement for new industrial expansions is estimated at roughly 100 GWh.

If half of all ship and boats have transitioned to a form of green fuel by 2040, the total annual energy consumption may rise to approximately 3 TWh (3000 GWh) by 2040. This is a 6 to 7 fold increase in total electricity consumption as compared to today, which evidently cannot be met by onshore wind, power, hydro power, solar power or tidal power.

5.1 OFFSHORE WIND FARMS

There are not very many technical options to choose between for the production of the large volumes of sustainable energy. Abroad, we see considerable development in offshore wind farms and it would not be an unthinkable option in the Faroe Islands. In spite of the fact that the cost of offshore wind power by 2030, is projected to be approximately double that of onshore wind turbines, and that the operating costs are nearly triple, refer to 'Expansion Schedule, Model Calculations'.

Based on the probable consumption forecast simulations show that by 2030 the Faroe Islands would need approximately 35 MW of offshore wind, which would need to increase to roughly 200 MW by 2040, see Figure 24. If the starting point is the high consumption forecast the demand will be 80 MW already in 2030, which will rise to roughly 460 MW by 2040. If the highly demanding maritime energy transition is included, there will be a considerably greater need to build offshore wind turbines.

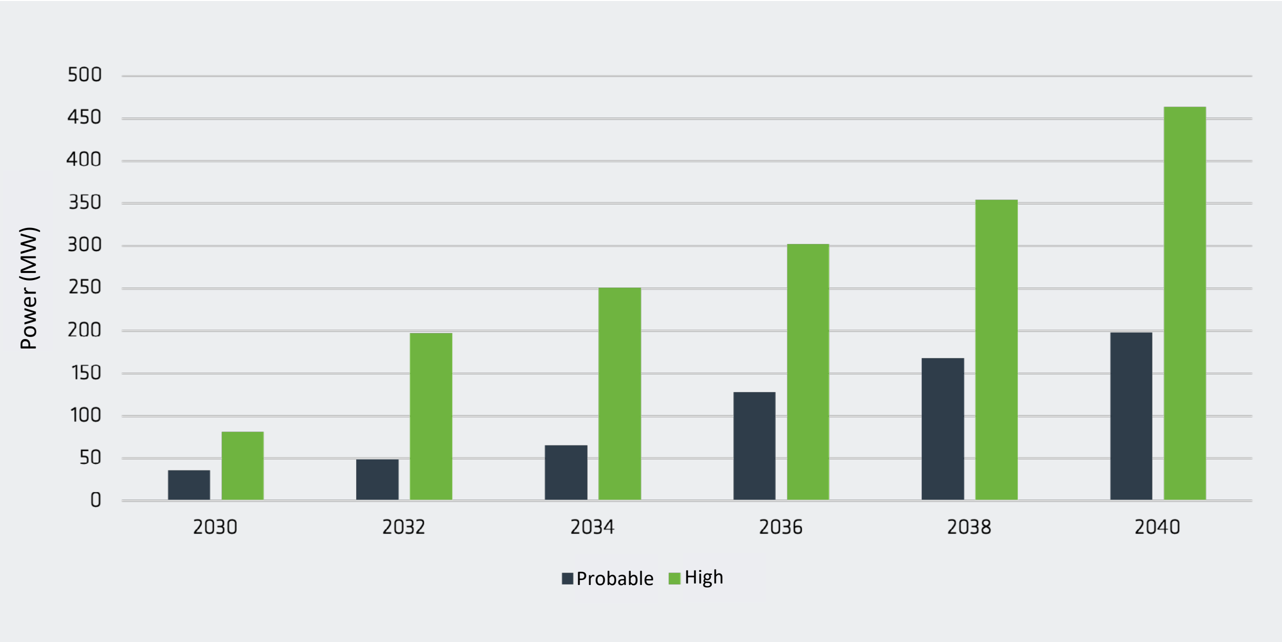


__Figure 24__ Offshore wind power, potential expansions up to 2040 applying both consumption forecasts

Very large volumes of energy may potentially have to be produced using offshore wind turbines. Lessons learned in other countries show that preparing an offshore wind farm is a protracted process, it is particularly time consuming to apply for licenses and authorisations.

The working party recommends that the Faroese authorities start to organise this work as soon as possible and also commission the necessary studies, so that an offshore wind tender can be launched when needed.

5.2 GREEN FUEL (P2X)

A maritime energy transition will, undoubtedly, mean that hydrogen produced from renewable energy will play a key role. At present, researchers are particularly interested in two fuels: methanol (CH_30H) and ammonia (NH_3). Methanol can be produced from hydrogen and CO_2, ammonia can be produced from hydrogen and nitrogen (N_2).

If such a fuel were to be produced in the Faroe Islands, ammonia would probably the more correct choice of the two, because there is no access to CO_2, whereas nitrogen can be extracted from the air.

Hydrogen, which is a linchpin in the production of green fuel, can, to a degree, be produced using surplus energy from wind turbines in the Faroe Islands. The reality with many wind turbines in the production system is often that green electricity generation is significantly higher than usage. This means that when there is a lot of wind and low consumption (at night, during weekends), wind, turbine generation has to be restricted. Electrification, pumped hydro systems, batteries and flexi usage (smart grids) are tools, which can increase efficiency. Forecasts show, however, that with a growing proportion of wind power in the system, a significant green power surplus will remain, see Figure 23.

As mentioned above, the production of hydrogen via water electrolysis is a technology, which is developing at a great pace around the world, partly for the same reason as in the Faroe Islands, namely in order to harness surplus energy.

The first step along this path in the Faroe Islands will be taken over the coming two years in a electrolysis project, which the Faroese Environment Agency is arranging together with SEV. DTU will be carrying out the analysis of electrolysis systems and how they can be tailored to the electricity system. An electrolysis plant would, in addition to hydrogen, also produce oxygen and heat. Mapping and coordination of potential users is therefore also necessary. Such users could include large transport companies, the aquaculture industry, district heating companies, and biogas plants. The results of the study will be a report that describes in detail how activity in this area could be launched at short notice.

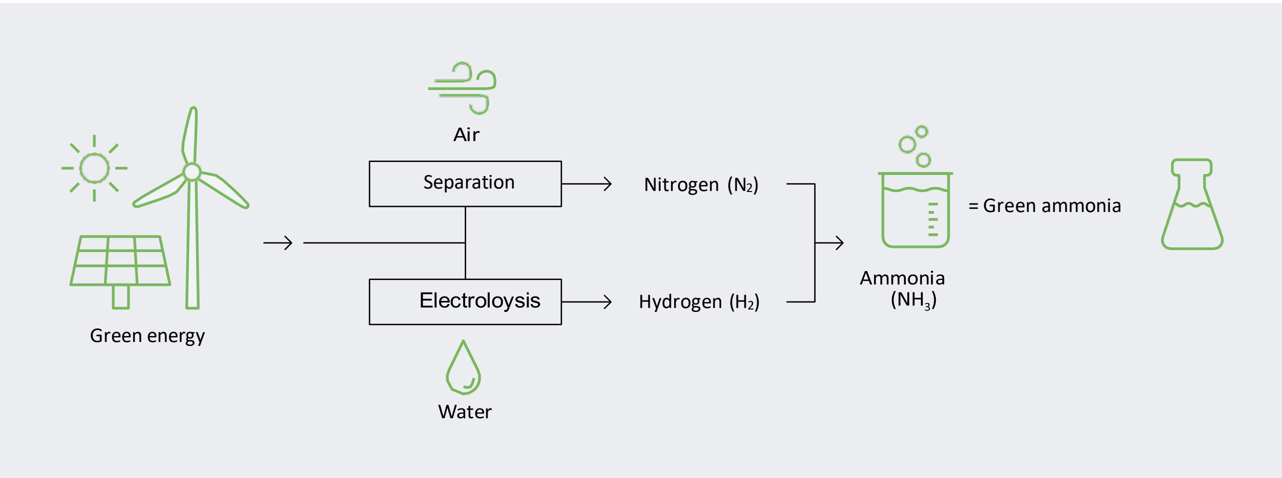


Figure 25 *Production of ammonia, simple description*

Abroad we see considerable **development** in off-shore wind farms and it is not unthinkable that it might be an **interesting** option in the Faroe Islands.

6. Dispatchable power

The concept of dispatchable power encompasses the electricity plants that can always feed electricity to the grid, regardless of season, weather, or wind. Although hydroelectricity is a constant source of energy, it is not available when, for example, there is no rain and the dams are empty. Wind power is, of course, not available when there is little or no wind, solar power is not available at night, or when there is no sun, and even tidal energy, which is a predictable source of energy, is not available at the turn of the tide. We therefore need energy plants and stores, which can meet electricity demand when the intermittent sources of energy are unavailable. Moreover, the Faroe Islands cannot rely on energy/power from other electrical grids in other countries, because there is no cable connection.

If electricity plants have to be built for the sole purpose of securing the electric grid when intermittent energy sources are not available, it would naturally have major financial implications, because it would necessitate large investments in plants, which should preferably not be used more than necessary.

At present, in principle only oil-fired plants can supply dispatchable power. This will most likely change in the future, when new electricity plants can burn green fuels, such as ammonia, or methanol.

Historical data shows that the need for dispatchable power grows in tandem with rising electricity consumption. The same ratio applies between a rise in electricity consumption (GWh) and grid load (MW) and, by extension, the demand for dispatchable power. If the same ratio applies in future, the demand for dispatchable power will grow, cf. Figure 26.

The projections for energy demand in Suðuroy show that the demand for dispatchable power will rise from approximately 9 MW today to roughly 14 MW by 2030.

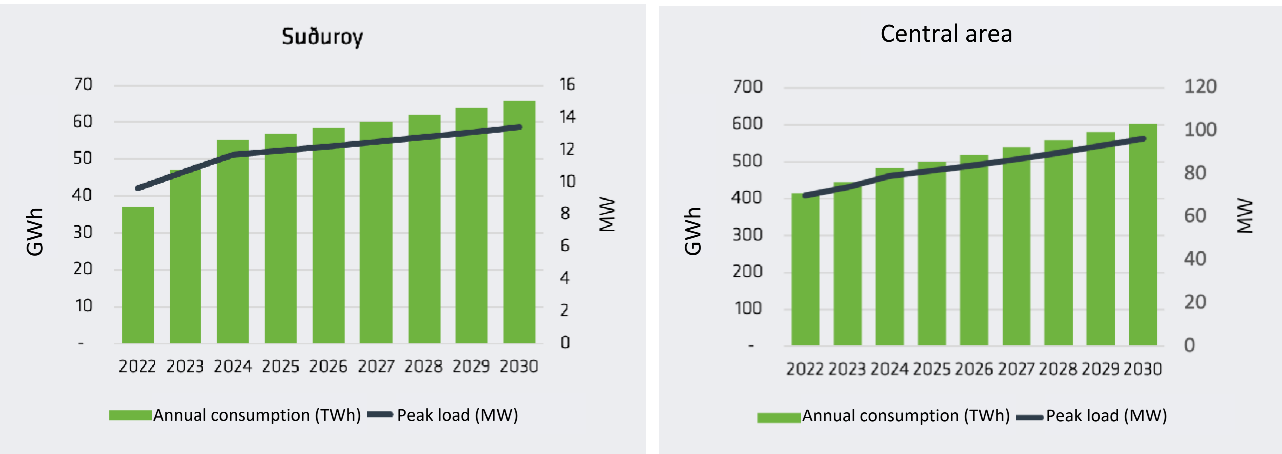


Figure 26 *Forecast for electricity consumption and peak load (probable forecast) in Suðuroy and in the central area*

Applying measures to spread demand more evenly over 24 hours, for example via flexi usage or smart grid systems where a proportion of consumption can be staggered, would enable distributing energy production over 24 hours and thereby potentially limiting the need to expand dispatchable power.

One way to assess the need for dispatchable power is to graphically examine how the grid load is distributed across all the hours in a year using a time graph, which shows how many hours a year the load exceeds a set numerical value. Figure 27 shows such a time graph for the load in Suðuroy and for the central area in 2022, 2025 and 2030.

It indicates that the peak load in the central area in 2030 is estimated at roughly 100 MW. It is also true that the load is only estimated to exceed 90 MW during approximately 50 hours per year. It is therefore worth considering whether there are opportunities to shift portions of usage in order to potentially limit the expansion of dispatchable power.

The graph for Suðuroy has a slightly different shape with a clear change in load for approximately 30 days (marked with a red dashed line), when the load is particularly high. This is based on usage by the plant in Tvøroyri, which, according to this graph had a particularly high energy consumption over approximately 30 to 40 days in 2022.

In relation to dispatchable power, the extent to which the hydropower plants could supply part of the dispatchable power for a limited period of time, in relation to the water levels in the various dams, also merits study.

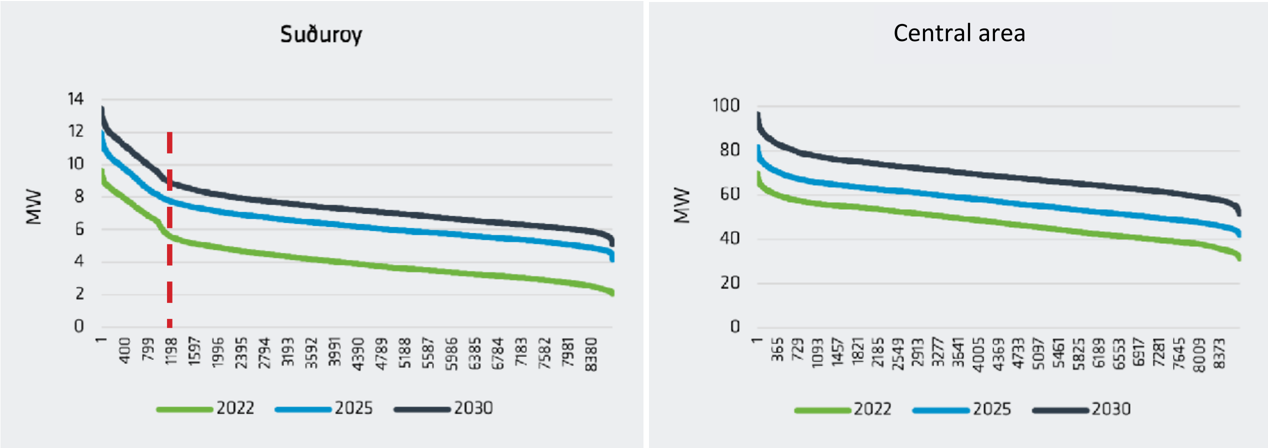


Figure 27 *Duration curves for Suðuroy and the central area*

The peak grid load projections do <u>not</u> take into account any increase caused by potential production of green fuel for maritime transport, <u>nor</u> does it take into account the electrification of existing industry on shore, though they will both most probably increase grid load. It is, however, possible that green fuel production and industry consumption in general could be directed to a certain extent, in order to limit the need to expand dispatchable power.

The working party recommends starting work immediately analysing how to secure a stable and reliable supply of electricity in the coming years, both with regards to meeting the actual energy demand (GWh) and to ensuring that there at any given time is sufficient power available (MW).

7. Preparations

In order to ensure an organised expansion of wind power, suitable areas should be identified and any necessary authorisations obtained from the relevant authorities and owners/tenant farmers. Another key element is windspeed measurements in the locations that are deemed suitable. In addition, impact assessment must be carried out in the areas.

7.1 PERMITS

When the working party, pursuant to the agreement, has identified an area, which is intended for the placement of wind turbines, the electricity supply inspectorate must make arrangements to ensure that all necessary licenses are obtained from the relevant authorities, including nature conservation authorities, municipalities and the Faroese Agricultural Agency in case of public land. In case of privately owned land, a lease or purchase agreement must be entered with the landowner.

As is clear in the expansion schedule (Table 1), several wind farms are to be installed in the coming years and it will be necessary to secure land for this purpose. Experience from previous wind power tenders have proven that in several cases it has been difficult to secure access to land, both in terms of ensuring that the most suitable areas are used, and in order to secure competition on equal footing when tenderers enter their bids.

It is therefore key that the relevant authority is endowed with the powers required to obtain land for this purpose.

7.2 MEASURING MASTS IN CONJUNCTION WITH WIND POWER TENDERS

In order to assess whether a location is suitable, and to assess the yield from a possible wind farm, robust measurements are required of factors such as wind speed, wind direction, and turbulence in the area where the wind turbines are to be placed. Measurements are taken at three different heights for example, 20 m, 45 m and 80 m. Experience from the Faroe Islands shows that measurements should be carried out continuously for at least two years prior to a tender in order to ensure that sufficient data is available to the tenderers.

It is recommended that the wind masts are installed using the same approach as for previous tenders, where SEV installs the measuring masts and operates them up to the tender, measurements are made available to all interested parties as soon as a measuring mast becomes operational. When a bid has been selected, the successful tenderer is required to reimburse to SEV the cost of the measuring mast and of its operation up to the day of the tender and will acquire ownership of the measuring mast.

The working party recommends installing measuring masts in the following order:

2024: Junkarahagi, above Kvívík
2024: Vestfelli, between Dalur and Skarvanes in Sandoy

7.3 ENVIRONMENTAL IMPACT STUDIES

According to the Electricity Supply Act an environmental impact assessment must be carried out and subsequently approved by the Faroese Environment Agency/Vernd. In the case of wind power tenders, the Faroese Environment Agency and SEV are responsible for ensuring that the necessary studies are carried out, including bird counts and other studies of biodiversity, in all locations identified for wind turbine installation.

A written report is to be submitted to the Faroese Environment Agency (Vernd department) for processing and approval.

It is, however, the responsibility of any company that wins a tender to complete the environmental impact assessment (type and number of wind turbines, actual placements, noise assessments, etc.), which must be submitted for final approval by Vernd before a definitive generations license can be issued.

The successful tenderer pays for the cost of these studies.

Given that solar power tenders are not organised in the same manner as wind power tenders, tenderers are required to carry out the necessary studies and environmental impact assessments pursuant to the provisions in the Electricity Supply Act, and these are subject to approval by Vernd and the Faroese Environment Agency before any licenses can be issued.

7.4 OTHER PERMITS AND LICENSES

It is the responsibility of the company that wins a tender to obtain definitive permits, these include construction permits from the relevant municipality, authorisations from the nature conservation authority, power grid connections, any necessary connections to main roads from Landsverk (Faroese Agency for Public Works) etc.

7.5 TENDERS

The working party, as per the agreement, shall prepare a detailed proposal for the terms and conditions of any wind power tenders, including size of the tender, placement, connection point and other particulars. See also section 4.1.

The working party also submits a detailed proposal for the terms and conditions of any solar power tender, including size and other particulars. See also section 4.2.

The electricity supply inspectorate, Elveitingareftirlitið, is in charge of the tender process.

8. Computer-generated images of wind turbine placements

In this section, we show computer-generated images of the various locations identified. These images are for guidance only, as the number of wind turbines, exact placement of each turbine and types of turbine may change. These computer images serve only as indications of possible placements.

8.1 KLIVALØKSHAGI

According to the expansion schedule, 30 MW are scheduled for installation in Klivaløkshagi in Sandoy. Computer generated Figure 28 shows seven 4.2-MW-turbines.

Figure 28 *Klivaløkshagi in Sandoy*

8.2 PORKERI

The expansion schedule indicates that 6 MW are to be installed in Porkeri. It is most likely that two large turbines will be set up in the same area where the other seven wind turbines are located, see Figure 29.

Figure 29 *Heimaripartur in Porkeri, Suðuroy*

8.3 GLYVRAFJALL

In Glyvrafjall 25 MW are listed for installation, see Figure 30.

Figure 30 *Glyvrafjall on Eysturoynni*

8.4 JUNKARAHAGI

In the area by Junkarahagi 20 to 25 MW are to be installed. Studies examining various options for the exact placement of wind turbines in this area are currently underway. Figure 31 is therefore for guidance only.

Figure 31 *Junkarahagi and surrounding area, Norðurstreymoy*

8.5 VESTFELLI

The mountain ridge between Dalur and Skarvanes, known as Vestfelli, is probably well suited to wind power generation. The expansion schedule stipulates that 50 MW are to be installed in the area. This is equivalent to roughly twelve 4.2 MW wind turbines.

Figure 32 shows the option of setting up a row of wind turbines. There is a room for approximately 16 turbines.

Figure 32 *Vestfelli on Sandoy*

NUDLAVIRKIÐ

umhvørvisstovan

SEV