An electric Norway – from fossil to electricity

Report

Case: An electric Norway – from fossil to electricity

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Date: May 8th 2019

Summary

Electrification is a fundamental factor in reducing Norwegian greenhouse gas emissions. If we replace most of present-day fossil-based energy use with electricity, we will see an increase in power consumption of 30–50 TWh per year. With equivalent growth in renewable power generation, this results in a halving of greenhouse gas emissions in Norway. The consequences for the transmission grid will probably be modest. To achieve zero emissions in the energy system, production of hydrogen can lead to a further increase of 40 TWh. Statnett has long said that the future is electric, and the trend we are now seeing shows that the pace of electrification is faster than ever.

Electricity in itself is a zero-emission energy carrier. In addition, existing Norwegian power generation is almost zero-emission, and there are opportunities to expand generation through the construction of new renewable generation in response to new consumption. In practice, electrification means increased use of renewable energy and lower greenhouse gas emissions. At the same time, use of electricity is far more energy-efficient than fossil energy use. Our estimates suggest that a switch to electricity may result in a combined reduction in Norwegian greenhouse emissions of around 25 million tonnes of CO_2 equivalents and a decline in primary energy use of around 55 TWh.

Electrification has become a far more attractive way of cutting greenhouse gas emissions in recent years, in both technical and economic terms. Developments in battery technology make it possible to electrify new areas quickly and on a large scale, particularly in parts of the transport sector. A switch from fossil fuels to electricity is already taking place, which will continue as batteries become cheaper and better. In addition, technology is being developed to electrify various industrial processes. Less noise and air pollution will generally be an important motivating factor in a switch to electricity.

The costs of new wind power are now so low that, at present-day power prices, it is cost-effective to install new wind power without subsidies in Norway. With all the investment decisions that have now been taken, we anticipate that Norwegian wind power generation will increase four-fold over three years and contribute to balance the new consumption that will come as a result of electrification. New consumption over time will also provide an economic basis for further expansion.

Figure 1: Breakdown of Norwegian energy consumption in number of TWh based on Statistics Norway's statistics for 2017

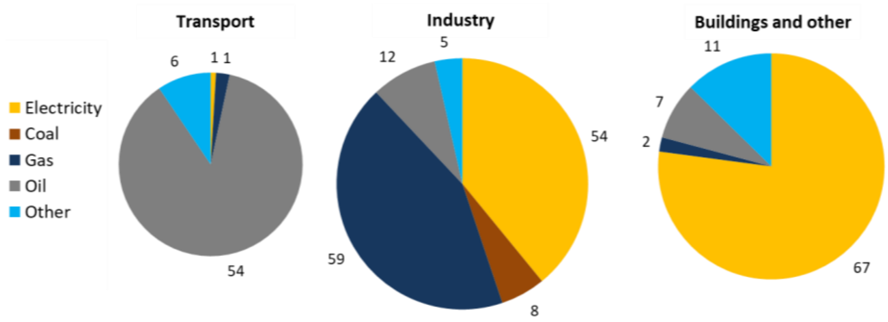
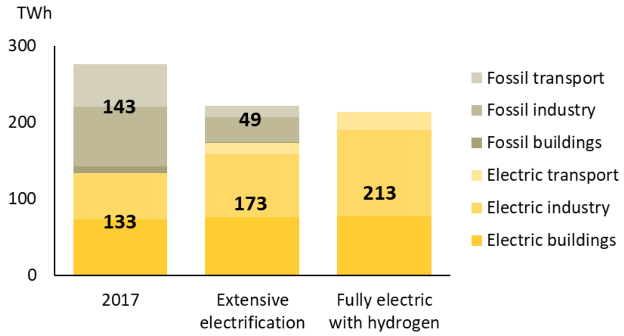


Figure 2: Trend in primary energy use with an increasing level of electrification



The figures above show that around half of primary energy use is already electric in Norway. Replacing present-day energy use can lead to 30–50 TWh of new power consumption in the scenario we call *Extensive electrification*. This represents an approximately 20–40 per cent increase from the present-day level. Large parts of this can come before 2040 if there is an active policy that facilitates electrification in both transport and industry, including the petroleum industry.

Extensive electrification does not include certain industries and heavy-duty or long-haul transport, where direct electrification will be difficult to implement. There are many alternatives here, and we see a higher level of competition between various zero-emission solutions such as hydrogen, carbon capture and storage (CCS) and bioenergy. If hydrogen produced by electrolysis gains ground, this will result in the greatest increase in power consumption, as shown in the scenario *Fully electric with hydrogen*. Power consumption from hydrogen production need not be a withdrawal from the Norwegian grid. This is because hydrogen production can take place far away from the actual consumption as it will be part of a larger market.

How new power consumption will alter the need for transmission grid capacity depends on factors such as geographical distribution, load profile over the year, price sensitivity and how quickly the development takes place. Our analyses to date show that growth in consumption has a modest impact on the transmission grid if volumes increase gradually over a long period and is spread geographically. We have previously shown this in a number of area studies and grid development plans. Increased power consumption from industry will often require local upgrades in the transmission grid, but there will rarely be a need for greater capacity in the grid channels between the regions. Higher power consumption in the transport sector results in a small increase of need for expansion in the transmission grid, but may bring forward many investments. The consequences overall are greater for the distribution grid, where for instance fast-charging stations can lead to high power locally.

The analysis in this report provides a basis for a better understanding of the opportunities and potential for growth in power consumption due to electrification. This has an impact on the uncertainty range for the Norwegian power balance, the cost-effectiveness of new generation and congestion in the transmission grid. Electrification is therefore a key factor in Statnett's analyses of needs and investments. In the run-up to the next Power System Plan (KSU) and Long-term Market Analysis (LMA) we will be taking a closer look at how consumption is broken down geographically in scenarios with a high level of electrification, and what relevant consequences this has for Statnett and the transmission grid.

Contents

1 Introduction

In this report, we calculate how much power consumption will increase if present-day fossil energy use becomes electric. We thus consider a simplified scenario where electricity becomes the preferred way of cutting emissions. As shown by ETC, among others, electrification is an effective way of cutting emissions in the energy system (Energy Transitions Commision, 2018).

Overall, there is some uncertainly linked to what the total power consumption could be with a high degree of electrification. Firstly, it is uncertain to what extent it is possible to electrify society, and to what extent this is cost-effective. Reduced costs in relation to the expansion of new renewable power generation, combined with improvements in battery and hydrogen technology, have made it easier to use electricity in several new areas. On the other hand, it is not realistic to electrify all fossil energy use, and much of the electrification will happen over a long period of time. In addition, the need for energy changes over time, partly as a result of increased transport needs and greater energy efficiency.

Electrification can take place with various technical solutions that also have an impact on power consumption. For example, there is a great difference in heating buildings with a heat pump compared with electrical resistance heating. If electricity is used to make hydrogen for use in industrial processes or transport, this will require around 2–3 times higher power consumption than direct use of electricity. Finally, it is not always the case that electrification must be a load from the Norwegian grid.

The figures we present apply to a conversion of present-day fossil energy use. We wish to point out that we make several simplifications in this report, such as basing the calculations on the energy use as it was in 2017. We therefore do not include the effect of possible future growth in energy use. Use of bioenergy is excluded from the calculations. We employ two methods to calculate power consumption. One is based on present-day primary energy use and what efficiency improvements can be expected from electrification. The other method uses figures from known experience of electrification. For example, we know the consumption for electric vehicles measured in kWh/km, the approximate annual distance driven and the number of vehicles. In total this gives us a figure in TWh for annual power consumption.

The calculations of energy savings and emission reductions are premised upon increased Norwegian consumption resulting in a corresponding increase in renewable power generation. Now that it is cost-effective to expand wind power without subsidies in Norway, we consider this to be a realistic assumption. The increase can partly also come from other sources.

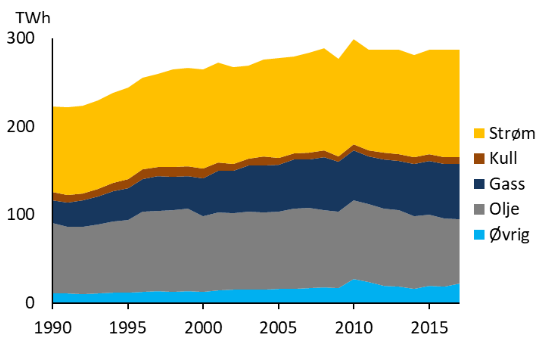


Figure 3: Historical trends in Norwegian energy use

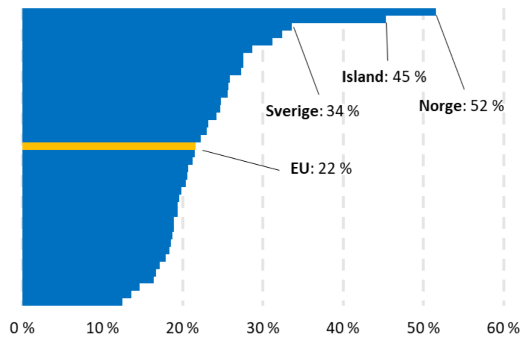


Figure 4: Proportion of electricity in energy use of European countries

In this report, we present possible scenarios with a very high level of electrification to show what increase in power consumption this can lead to. These differ from our latest consumption forecasts, which are more conservative and were published in the report Long-term Market Analysis 2018 (Statnett, 2018). The forecasts have around 15 TWh growth in gross consumption by 2040 in Norway as a result of electrification.

2 Electrification of **transport**

The transport sector currently has a low level of electrification. Only 1 out of 62 TWh of energy use was electric in the Statistics Norway figures for 2017. Our estimates for extensive electrification give 14 TWh of electricity consumption in the transport sector.

In Long-term Market Analysis 2018, our forecasts show power consumption of 10 TWh in Norwegian transport in 2040. This comes from large growth in electric cars, electric ferries, buses and vans, but does not mean that the whole of transport sector will be electric.

The Norwegian Water Resources and Energy Directorate (NVE) has published four reports on electrification of the transport sector (NVE, 2016) (NVE, 2016) (NVE, 2017). NVE estimates that electrification of the transport sector could result in 12 TWh power consumption, based on present-day energy use. This figure includes cars, vans, buses, trucks and motorcycles, but not ferries, ships or aircrafts.

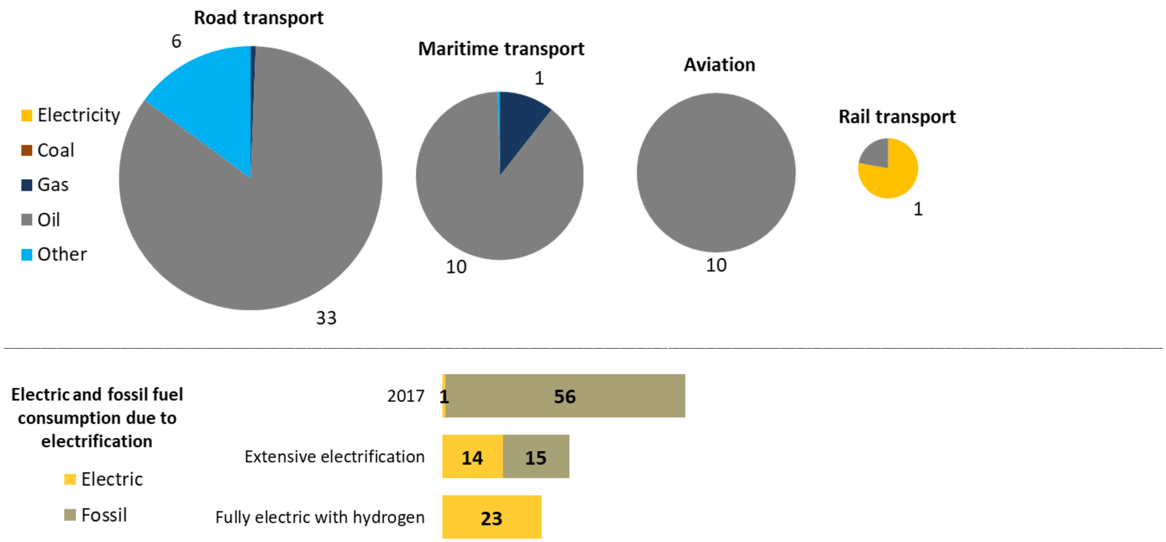


Figure 5: Energy use in TWh for the transport sector in 2017 from the Statistics Norway energy balance and with electrification.

Electric cars and light vehicles

Development in electric cars has been rapid, and at the start of 2018 there were more than 140,000 electric cars on Norwegian roads (SSB, 2018). The batteries and electric cars are becoming cheaper, and the Norwegian Parliament has suggested a ban on new sales of fossil fuelled cars from 2025. If all 2.7 million Norwegian cars are replaced by electric cars, this will result in power consumption of around 6.5 TWh. This assumes that the average car is driven 12,000 kilometres annually and uses 0.2 kWh/km.

Internal combustion engines in cars normally have an efficiency of between 25 and 40 per cent, new diesel engines being the most efficient. Even with network losses, charging losses, battery losses and losses in the electric motor, energy use in an electric car will be less than half that of an equivalent car with an internal combustion engine. In other words, a switch to electric cars will result in more than halving of primary energy use.

Vans, trucks and buses

Cheaper fuels, and thus lower operating costs, are an important factor in larger vehicles also choosing battery-electric models. The challenge is that these vehicles often need either very large batteries or frequent access to charging points.

In total, vehicles on the roads other than passenger cars can result in around 5 TWh of electricity consumption. The NVE report on extensive electrification of the transport sector estimates that vans can result in 1.8 TWh of power consumption, urban buses 0.5 TWh, other buses and coaches 0.2 TWh, other heavy vehicles 1.4 TWh and light lorries 1.0 TWh (NVE, 2016). This is based on statistics and assumptions on the number of vehicles, consumption per kilometre and annual distance driven.

A report from the Institute of Transport Economics (TØI) analyses the potential to electrify small goods vehicles (TØI, 2018). Smaller vehicles have several good electric alternatives, while heavy-duty, long-haul vehicles still lack cost-effective fully electric models. In TØI's zero-emission pathway, 63 per cent of small goods vehicles are electric in 2030.

Maritime and rail transport

Ferry links with battery and hybrid solutions have already come a long way in Norway. The world's first fully electric ferry, Ampere, started operating in 2015. A number of ferry routes will be replacing diesel with electricity as their source of power over the next few years (TU.no, 2017). Many of Norway's 112 ferry routes are well suited to become battery-electric, and there are plans to convert or replace the diesel ferries. The Norwegian Environment Agency has calculated that electrification of all Norwegian ferries and passenger ships will lead to around 0.8 TWh of power consumption (Miljødirektoratet, 2015).

It is almost impossible with present-day technology for larger ships and boats that sail long distances without access to charging points to change over to battery-electric propulsion. Hydrogen emerges here as one of several possible solutions to cut emissions. Hydrogen ferries are under development, for instance to operate the Hjelmeland route. Our calculations show that consumption to produce hydrogen by electrolysis for Norwegian maritime transport may be up to 5 TWh.

Power supply from shore means connecting to the grid when maritime vessels are docked at the quayside, and therefore turn off diesel engines and generators. DNV GL has calculated that ships use around 2 TWh of fuel when they are in port. Most of this consumption comes from offshore supply ships, passenger ships and cargo ships. Electrification of all this would result in just under 1 TWh of electricity consumption (DNV GL, 2015).

Norwegian rail transport uses 0.2 TWh. Out of Bane NOR's total of 3,900 km of train routes, 1,400 km are non-electrified today (Jernbanedirektoratet, 2018). Solutions with hydrogen, battery-electric, hybrids or contact lines may be possible for these.

Aviation

Domestic aviation in Norway emits around 3.5 million tonnes of CO_2 equivalents of greenhouse gases annually. Greater use of biofuels or electric aircraft and lower use of present-day types of aircraft are essential if these emissions are to be cut. Avinor has, for example, opened discussions on introducing electric aircraft in Norway in the long term. By 2030, it will be possible to use hybrids or fully electric aircrafts in the short-haul network. Avinor believes that all domestic traffic can be electric in 2040.

The statistics for 2017 show energy use of 4 TWh for domestic and 6 TWh for international aviation. The levels of traffic in the short-haul network account for a very small proportion of Norwegian traffic, and electrification of this will therefore signify a negligible quantity of power consumption.

As electric aircraft still require technological development, it is somewhat uncertain how energy-efficient they will be. An estimate if all domestic flights were electric is just under 2 TWh of power consumption. This is conditional on a significant improvement in energy density in batteries.

3 Electrification of industry

The industrial sector, including oil and gas extraction, emits around 27 Mt CO_2e annually, of which 25 Mt CO_2e is covered by the EU quota market (DNV GL, 2018). Our simple estimates show that 13 Mt CO_2e can be cut by extensive electrification. This will lead to 23 TWh of new power consumption, and far more if hydrogen is used to cut remaining fossil energy use.

For many of the industrial processes, there is currently no technology to replace fossil fuels directly with electricity. Electricity can nevertheless be used to produce hydrogen or synthetic hydrocarbons. This electrification of industry is particularly relevant in the production of heating from gas and oil-fired boilers. The extent to which it is technically possible to electrify other industrial processes is uncertain and varies greatly between the different industrial processes.

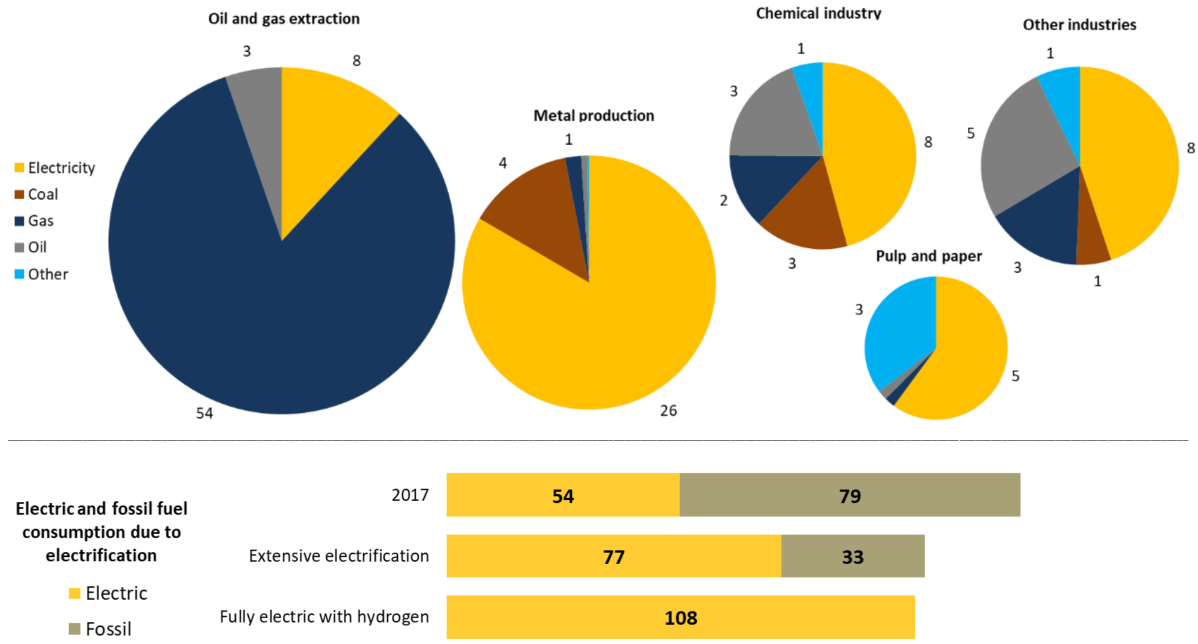


Figure 6: Energy use in TWh for industry in 2017 from Statistics Norway's energy balance and with electrification. Note that Statistics Norway's definition of industry includes several sectors that are not included in the term power-intensive industry.

Extraction of oil and gas

A number of platforms on the continental shelf are already fully or partially electrified. This applies to the Troll A, Valhall, Gjøa, Goliat and Martin Linge fields. In 2017, 8 TWh of electricity, 54 TWh of gas and 3 TWh of oil were used for extraction of oil and gas. Large parts of gas consumption come from gas turbines located on the platforms. In addition, some comes from production ships, gas or oil-fired boilers, engines, compressors and pumps.

The Norwegian Petroleum Directorate has estimated installed capacity at around 3,000 MW of gas turbines on the continental shelf (Oljedirektoratet, 2008). The total need for power from the shore will be lower, both because of many of these are on standby and because of losses in the gas turbines. Gas turbines with heat recovery have approximately 40 per cent efficiency. According to a report from Unitech, full electrification of the continental shelf in 2015 would amount to nearly 1,600 MW, which is probably equivalent to around 12 TWh. This includes losses in converters and transmission (Unitech Power Systems, 2007).

Electrification of the continental shelf can also be accomplished using offshore wind turbines. This leads to less of the power consumption being provided from the onshore grid.

Metal industry

The Norwegian metal industry is a large consumer of power. Aluminium plants are a good example of this, where electricity is used as an input factor in electrolysis to produce aluminium.

Production of ferrous alloys makes large-scale use of coal or coke to remove oxygen. Conversion with the use of hydrogen, gas or biofuel as reduction agent in the metallurgical industry is often technically possible. The HYBRIT project in Sweden, for example, shows that the iron and steel industry have ambitions to cut emissions using hydrogen. It is more challenging to implement direct electrification in this sector. New power consumption might therefore arise through production of hydrogen for metal production.

Chemical industry

According to figures from Statistics Norway, the chemical industry uses around 5 TWh from fossil sources, evenly divided between gas and coal. This category includes industries producing industrial gases, chemicals, fertilisers, plastics and rubber. Parts of fossil fuel consumption are linked to the burning of waste gases and residual products, and electrification is of little relevance here.

Production of commercial fertiliser uses natural gas for the production of hydrogen and then ammonia. A possible low-emission solution is to produce ammonia using renewable hydrogen from electrolysis.

Building and construction

The building and construction sector currently use many machines that run on fossil diesel. Construction machinery accounts for around 18 per cent of CO_2 emissions in Oslo. In addition to greenhouse gas emissions, electrification will make it possible to reduce noise and various types of pollution. Use of oil-fired machinery for drying and heating is prohibited on Norwegian building sites from 2022.

Battery-electric excavators, wheeled loaders, dumpers and concrete vehicles, for example, have already been developed. In Statnett, we are working on cutting emissions from building and construction activities. This work has demonstrated the use of electricity for machinery in tunnelling, for example for boring and injections. Renewable, palm-oil-free and non-food-based diesel is used for trucks and other machinery (Statnett, 2018).

Other industry

The cement producer Norcem in Brevik has launched a project to study whether electrification can be accomplished. This cement producer emits large quantities of CO_2 both through the process itself and from energy use (Norcem, 2018). Direct electrification could therefore cut some of the emissions, but not all of them. The mineral wool producer Rockwool has recently decided to replace the use of coke with a new electric arc furnace.

In the food industry, gas in particular with 1 TWh consumption, is used in various processes in food production. Where the processes use gas to produce a naked flame, it is difficult to replace these with direct use of electricity. Other industry groups that use oil, coal or gas totalling more than 0.1 TWh include quarrying, the pulp and paper industry, production of plastics, other petroleum products and glass.

4 Electrification of **buildings**

Transport and industry account for the greater part of Norwegian fossil energy use and greenhouse gas emissions, but buildings and other commercial activities also use fossil energy. In the long term, agriculture, forestry and fisheries will increase their use of electric machinery and equipment. Households and services (except transport) already use little fossil energy today, and a ban on oil firing is further reducing use.

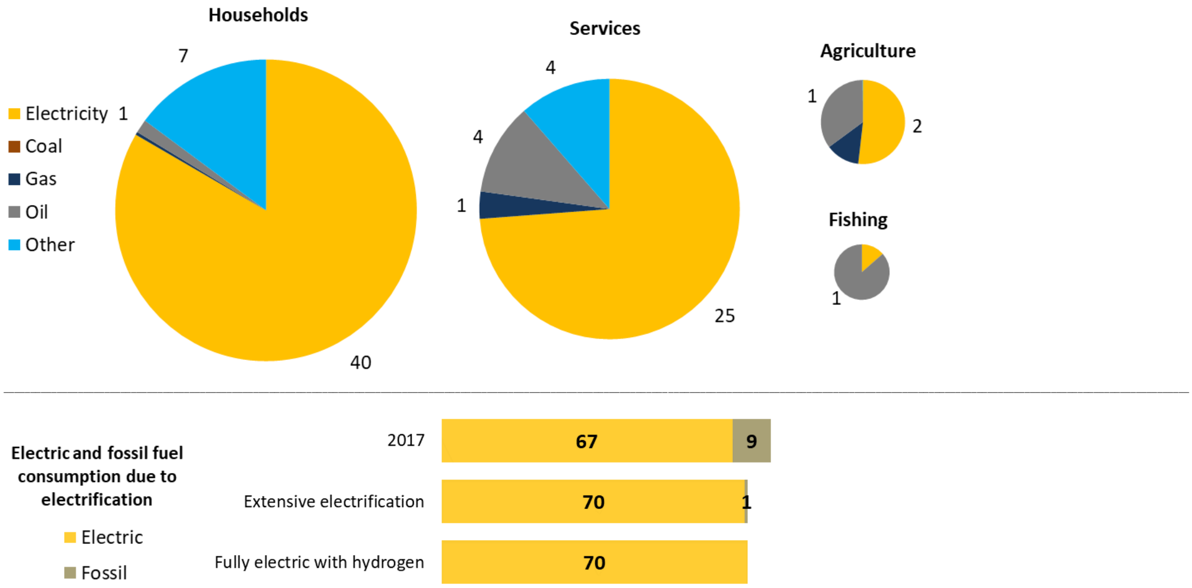


Figure 7: Energy use in TWh for building and commercial activity in 2017 from Statistics Norway's energy balance and with electrification

Households and services

The building sector is largely electric as very little of the heating requirement is met by fossil energy sources. Parts of energy use for heating using wood firing or district heating are mainly based on biomass, waste and electricity

A ban on heating oil and paraffin for heating will take effect from 2020. A total of 4.8 TWh of oil products was used by households and services in 2017. Some of this will probably be converted to electric heating as a result of the ban. If it is replaced by heat pumps, this will result in three times lower power consumption than electric panel heaters, electric boilers or similar.

Primary industries

In agriculture and forestry, diesel equivalent to around 3 TWh is used for tractors and other agricultural and forestry machinery. Biodiesel is often mentioned as the preferred alternative for cutting emissions, but more and more battery-electric variants have come onto the market. The potential for electrification is probably around 1 TWh of new power consumption.

Up to 80 per cent of production from Norwegian fish farming is cost-effective to electrify, which will result in an increase of around 0.1 TWh in power consumption, according to DNV GL (DNV GL, 2018). This includes fuel for work boats, equipment on boats and equipment at the farms. Like other coastal transport, these can be linked to the shore power supply when they are close to shore, as mentioned in section 2. Another report published by ABB points to measures that can lead to a 75 per cent reduction in both diesel consumption and greenhouse gas emissions from salmon production (ABB, 2018). According to NELFO, battery hybrids can halve CO_2 emissions in the coastal fleet. Many of the fishing boats are old, and electrification will result in less noise, higher energy efficiency and lower operating costs (NELFO, 2017). Overall, we believe that electrification of the fishing industry will lead to just under 0.5 TWh of power consumption.

5 Total effect on energy and emissions

Electrification offers many advantages. We examine what it means in terms of increased power consumption, lower primary energy use, reduced emissions of greenhouse gases and impact on the transmission grid. In *Extensive electrification*, 95 out of 143 TWh of fossil energy use is replaced by electricity. To demonstrate the effect of cutting the remaining parts, where we consider direct electrification to be hard to attain, we also calculate a *Fully electric with hydrogen* scenario.

The table below shows the results of a simplified analysis based on the statistics on energy balance (measured in TWh) and greenhouse gas emissions (measured in Mt CO_2e). Production and use of hydrogen result in higher energy losses but can replace the use of fossil fuels in parts of the metal industry, chemical industry, petroleum industry, aviation and shipping.

	Energy use in 2017					*GHG emissions in 2017*	*Extensive electrification*			*Fully electric with hydrogen*
Consumption group	Elect-ricity	Coal	Gas	Oil	Other	Total	*New power consumption*	*Energy savings*	*Cuts in emissions*	*New power consumption*
Transport	**1**	**0**	**1**	**54**	**6**	**17**	**13**	**27**	**11**	**22**
Road transport	0	0	0	33	6	9	11	23	9	11
Rail transport	1	0	0	0	0	0	0	0	0	0
Aviation	0	0	0	10	0	4	1	1	1	5
Maritime transport	0	0	1	10	0	4	2	3	1	7
Industry	**54**	**8**	**59**	**12**	**5**	**26**	**23**	**22**	**12**	**54**
Metal production	26	4	1	0	0	5	2	0	1	6
Mining and minerals	1	1	1	1	1	1	2	0	0	2
Chemical industry	8	3	2	3	1	2	3	1	0	8
Food industry	3	0	1	0	0	0	1	0	0	2
Pulp and paper processing	5	0	0	0	3	0	0	0	0	0
Building and construction	1	0	0	3	0	1	1	1	1	2
Oil and gas extraction	8	0	54	3	0	15	15	20	9	33
Other industry	2	0	0	0	0	2	0	0	0	0
Buildings and others	**67**	**0**	**2**	**7**	**11**	**8**	**3**	**5**	**2**	**3**
Agriculture and forestry	2	0	0	1	0	6	1	1	2	1
Fisheries	0	0	0	1	0	0	0	1	0	1
Households	40	0	0	1	7	1	0	1	0	0
Services	25	0	1	4	4	1	2	4	0	2
In total	**121**	**8**	**63**	**73**	**7**	**51**	**40**	**55**	**25**	**80**

Extensive electrification results in 30–50 TWh of new consumption

The potential for new power consumption based on direct electrification of present-day energy use is around 40 TWh according to our calculations. We nevertheless say 30–50 TWh in order to emphasise the uncertainty based on the fact that not everything can be easily electrified, that electrification is not always the best way of cutting emissions and that final energy consumption will change over time. In addition, the answer is dependent on what assumptions we make.

When we look at the calculations for what complete phasing-out of fossil energy use leads to, the last part is replaced by hydrogen, for example. In *Fully electric with hydrogen* we have assumed that parts of the petroleum sector and international shipping and aviation will go further to achieve zero emissions. Low efficiency leads to a further 40 TWh of power consumption in comparison with *Extensive electrification*.

In the figure below we show only figures from fossil and electric primary energy use. Use of biomass is thus excluded, as we are looking here at electrification of fossil energy use. Note also that we calculate as though consumption is always covered from the Norwegian grid, which is not necessarily the case. Hydrogen may be produced in Norway, for example, even though it is used in other countries. Production without connection to the grid is also relevant.

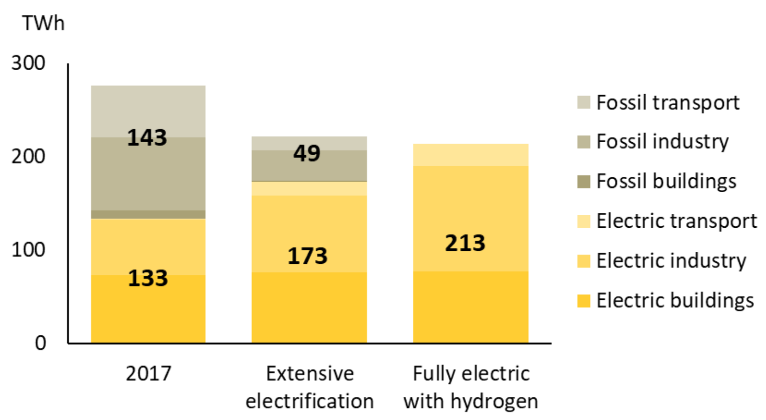


Figure 8: Primary energy use in 2017 from fossil sources or electricity, and change through electrification

Electrification provides great energy savings

The table on the previous page shows that *Extensive electrification* provides 40 TWh of new power consumption that replaces 95 TWh of fossil energy, and the energy saving is therefore 55 TWh. Conversion from fossil to electric energy thus results in significant reductions in primary energy use due to the differences in efficiency.

This assumes that the increase in power consumption leads to new renewable power generation within the country. We consider this to be a realistic assumption as it is now cost-effective to construct new wind power plants without subsidies. Parts of the increase may nevertheless arise from sources other than wind power, for example hydro and solar power. More consumption in isolation will raise power prices and boost the cost-effectiveness of new renewable generation.

We have assumed efficiencies for each of the different categories of energy use for oil, gas, coal and electricity. This tells us how large the consumption of electricity is and how much produced energy is saved. We have assumed around 75 per cent fossil efficiency for most industrial processes, while we assume that this is between 25 per cent and 40 per cent for transport. We have assumed electric efficiency of close to 100 per cent, except for areas where heating by heat pump is possible.

Renewable hydrogen produces considerably smaller energy savings than direct electrification, as energy is lost in production through electrolysis, compression, storage and use of hydrogen. We have assumed an optimistic overall efficiency level of 60 per cent for use in industrial processes and 40 per cent for transport with fuel cells. This depends on a number of assumptions, and it is therefore uncertain how well these figures will agree with practice. In our calculations, we have limited the use of hydrogen for areas where direct electrification appears unattainable.

Norwegian greenhouse gas emissions can be significantly reduced

Norwegian power generation is almost emission-free. Most Norwegian CO_2 emissions therefore come from industry, transport and other commercial activity. In 2017, Norwegian domestic greenhouse gas emissions totalled 52.7 Mt CO_2e. Including emissions from international shipping and aviation, Statistics Norway estimates the total at 67.3 Mt CO_2e (SSB, 2018).

In *Extensive electrification*, the total decrease in emissions is 25 Mt CO_2e, which is equivalent to nearly half of domestic greenhouse gas emissions. Of this, 11 Mt CO_2e is from the transport sector and 7 Mt CO_2e from oil and gas extraction. These calculations are uncertain estimates to give an impression of the order of magnitude. As mentioned earlier, we assume no increase in emissions from power generation as a result of increased consumption.

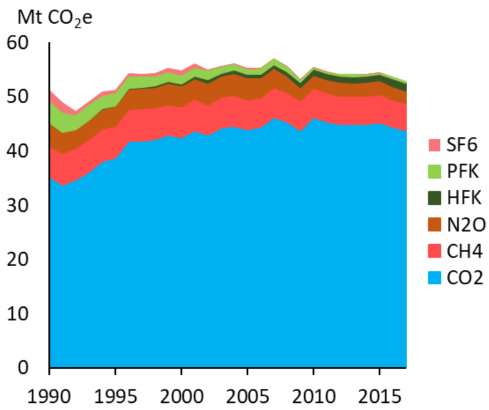


Figure 9: Emissions of different greenhouse gases 1990–2017

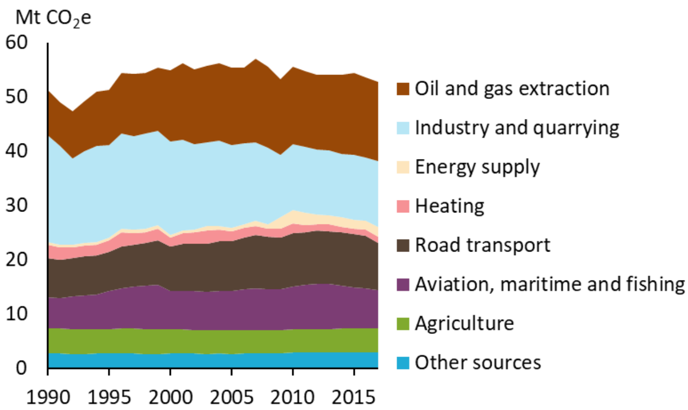


Figure 10: Greenhouse gas emissions broken down by source 1990–2017

6 Consequences for the power system

Development such as we outline in the extensive electrification scenario will probably have modest consequences for the transmission grid. This is due to both good geographical spread of the new consumption and since the development taking place over time. The challenges will be greater in the distribution networks.

Electrification will take place gradually over time

A key question is how quickly the transition to a more electric society will take place. We know that oil heating and ferry routes using diesel are already being phased out. Electric cars are gradually taking over the car fleet, and electric alternatives are gradually also becoming viable in other sectors.

So far, this report has looked at electrification without taking account of other future changes. Population growth, building quality, industrial activity and new data centres, for example, are important drivers in the future development of power consumption. Significant energy efficiency improvements in existing consumption may contribute to growth in consumption being lower than 30–50 TWh. On the other hand, increased use of hydrogen from electrolysis in Norway will drive up consumption.

In Figure 11 and Figure 12 we outline two ambitious paths to an emission-free energy system in 2050. These illustrate a situation in which cuts in fossil energy use take place rapidly in the transport sector and how other drivers can influence the long-term picture. Growth in transport activity in this example contributes to a further 4–6 TWh of power consumption for the potential in 2050. The figure on the left represents rapid and extensive electrification, but where bioenergy or CCS makes the Norwegian energy system carbon-neutral by 2050. On the right, difficult cuts in emissions are attained with hydrogen, which results in greater growth in power consumption. Total power consumption in 2050 in these scenarios is 147 and 166 TWh, respectively. Improved energy efficiency and other drivers thus result in a smaller increase than in the calculations based on 2017 figures for fossil energy use.

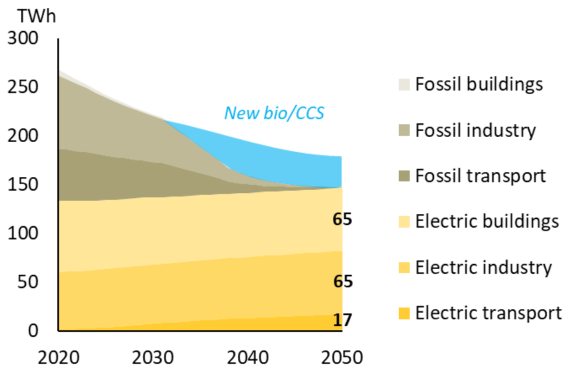


Figure 11: Fossil and electric primary energy use towards 2050 for Extensive Electrification

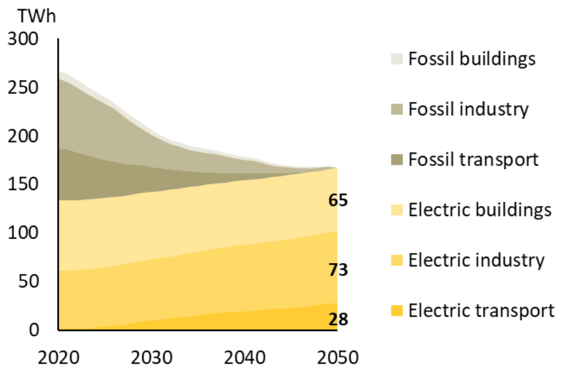


Figure 12: Fossil and electric primary energy use towards 2050 for Fully Electric with Hydrogen

Previous analyses have shown modest consequences for the transmission grid

How new power consumption changes the need for transmission grids depends on a number of factors:

- Geographical distribution and relation to growth in generation
- Load profile over the year and temperature dependence
- Sensitivity to changes in power prices
- How rapidly development takes place and predictability

We can generally say that the consequences of increased power consumption are greatest in the distribution grid. Local restrictions in distribution grids and levelling of local peak loads lead to the load challenges not having such great consequences at a higher voltage level. This does not mean that there is always available capacity for new consumption in the transmission grid without some form of grid investment. Increasing power consumption in industry and the petroleum sector will often necessitate local and in some cases more regional upgrades to the transmission grid. This means investments in both substations and power lines.

Where the growth in consumption occurs has a great impact on the need for transmission grid capacity. Electric cars will mainly lead to many relatively small loads spread around in the vicinity of urban areas, or along main roads. This type of consumption growth therefore has little impact on the overall flow patterns. At the same time, electric transport is one of the reasons why we expect long-term growth in Norwegian power consumption, and in many cases, this can expedite grid investments. Consumption is more unevenly distributed across the country for other types of electrification. Fishing vessels, for example, are more concentrated in Northern Norway, and the petroleum industry is most concentrated in Western Norway. Which consumption groups are electrified first may therefore be of significant importance on the need for grid capacity.

In this report, we summarise annual power consumption in a shift to electricity. How this consumption is distributed across the country, and in particular how the use of power at peak load looks like, is also essential to determine the need for grid capacity. For example, grid upgrading will be necessary earlier in time if everyone fast-charges at the same time than if charging only takes place at night or in periods of high energy surplus. Electrification results in increased consumer flexibility, for example from electric cars that can manage charging according to price signals or ships with shore power supply that have standby generators on board. These factors may lead to grid upgrades being postponed.

Our previous analyses show that electrification is not a major driver of increased capacity in the transmission channels between the Norwegian regions. For example, our analyses for the 2017 Power System Plan showed that an increased proportion of electric cars has little impact on the overall flow patterns in the transmission grid. Geographical distribution and favourable charging profile contribute to this.

We will study the consequences of extensive electrification more closely

Electrification is an important topic that we will look at more closely in continued analyses. This means implementing scenarios with a very high degree of electrification in our grid and market models to look more closely at the effects, for example on the need for grid capacity. Ahead of the next Power System Plan and Long-term Market Analysis, we will therefore analyse in more detail how consumption is distributed geographically in scenarios with a high level of electrification, and what consequences this has for the transmission grid.

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