PLATON

Future electricty prices

Published: 22 May 2020

by: Kevin R. Kaushal, Lars Lindholt and Hidemichi Yonezawa.

This study simulates the effects of different future electricity prices on the performance of the Power-Intensive Industries. Our results show that both Non-ferrous metals and Iron and steel production react strongly to variations in future electricity prices.

Effects of changes in electricity prices on the power-intensive industries and other sectors in Norway towards 2030

Abstract

In this study we simulate the effects of different future electricity prices on the performance of the power-intensive industries in terms of production, employment, investment and trade over the 2020-2030 period. We apply Statistics Norway's SNOW model, a computable general equilibrium projection model of the Norwegian economy.

Our results show that both Non-ferrous metals and Iron and steel production react strongly to variations in future electricity prices. In our *high price scenario*, the Norwegian and European electricity prices are around 50 per cent higher than the reference electricity price in 2030. This leads to a reduction in accumulated output the next decade of 36-40 per cent in Non-ferrous metals and 32-33 per cent in Iron and steel compared

to the reference electricity price situation. The main reason for the larger decline in the production of Non-ferrous metals than Iron and steel, is that this sector is more power-intensive.

In our *low price scenario*, both the Norwegian and the European electricity price decline so that the price is around 40 per cent lower in 2030 compared to the reference electricity price. Assuming no electricity efficiency gains in a low price environment, accumulated output over the next decade increase by 52 per cent and 36 per cent in Non-ferrous metals and Iron and steel, respectively, compared to the reference price scenario. Because Iron and steel is less power-intensive than Non-ferrous metals, they gain relatively less from lower electricity prices.

For both sectors the relative effects of the electricity prices on export, CO_2-emissions and employment follow to a large extent the same pattern over time as the impacts on output.

Introduction

Future electricity prices will potentially impact the Norwegian macroeconomy, industrial pattern and greenhouse gas emissions. This study will particularly focus on the Power-Intensive Industries (PII) in terms of production, employment, investment and trade. The PII are large users of electricity as they consume almost 90 per cent of the final electricity use in Norwegian manufacturing.

We apply Statistics Norway's SNOW model, a computable general equilibrium (CGE) projection model of the Norwegian economy, with 46 producing sectors and various household and public consumption sectors. We will simulate the effects of different future electricity prices, particularly on the performance of the PII.

NVE (2018) assumes that the electricity interconnector cables under construction from Norway to both Germany and the UK will be operational by 2022. Further, the report assumes that more power cables will reduce the price difference between Norway and Europe. As a result, NVE expects the price of electricity to increase in Norway in their reference scenario. For each cable we add to Europe, Norwegian electricity prices will approach the European ones, albeit in a slow pace. In addition to the reference scenario, we apply the high and the low Norwegian and European power price in NVE (2018). The high electricity price case is above all linked to higher prices of CO_2-quotas in the EU to gradually phase-out fossil power production. In the low electricity price scenario, the CO_2-price is set to a symbolic low value. Further, we will study how sensitive the results are to changing world market export prices and changes in energy efficiency in the PII.

Description of the power-intensive industries in Norway

The PII can be described as sectors that use relatively more electricity than other sectors. We have listed the various PII in Table 2.1 below as they are defined in the SNOW model and emphasize that for some sectors only subgroups can be characterized as power-intensive. For the PPP sector (Paper products/publishing) it is only the production of paper/paper products that can be described as power-intensive. For OIL (Refined petroleum products, incl. Chemicals, rubber, plastic products, pharmaceuticals) the same characterization can be made for chemicals.[1] However, OIL is highly energy-intensive due to its large use of oil and gas, rather than electricity. For NMM (Non-metallic minerals) the cement, lime and plaster subgroup can be regarded as power-intensive. The whole of I_S (Iron and steel) and NFM (Non-ferrous metals) can be regarded as highly dependent on electricity.

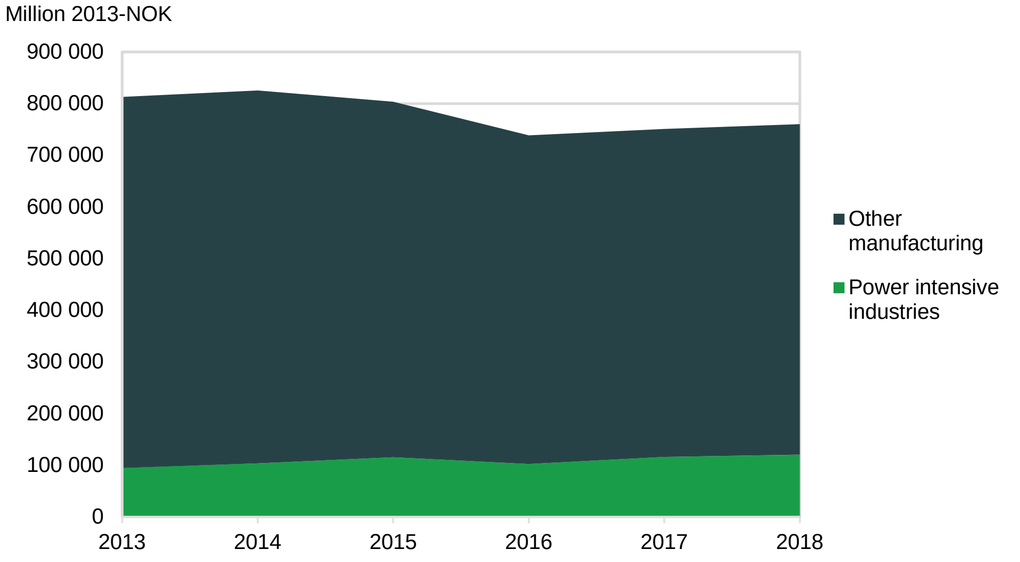
Table 1 Description of the power-intensive industries in the SNOW model

SNOW-code	Sector	NA-code	Description
PPP	Paper products/publishing	23170	Paper and paper products
		23180	Printing and reproduction of recorded media
		23580	Publishing
OIL	Petroleum, coal products and Chemical, rubber, plastic products, pharmaceuticals	23190	Coal and refined petroleum products
		23201	Chemicals
		23207	Chemicals products
		23208	Production of base plastic and synthetic rubber
		23210	Pharmaceuticals
		23220	Rubber and plastic products
NMM	Non-metallic minerals nec	23231	Glass and glass products
		23232	Refractory products, clay building materials and ceramic products
		23235	Cement, lime and plaster
		23236	Articles of concrete, cement, and plaster
I_S	Iron and steel	23241	Iron, steel and ferro-alloys
		23245	Casting of metals
NFM	Non-ferrous metals nec	23243	Aluminium
		23244	Other non-ferrous metals

The PII are important when it comes to production value in Norway. We see from Figure 2.1 that the share of PII production of total manufacturing increases from around 12 per cent in 2013 to 16 per cent in 2018, when it reaches over 120 billion NOK in 2013-prices (Statistics Norway, 2019a).

[1] The refined petroleum sector includes chemicals, rubber, plastics and pharmaceuticals to avoid identification of plants.

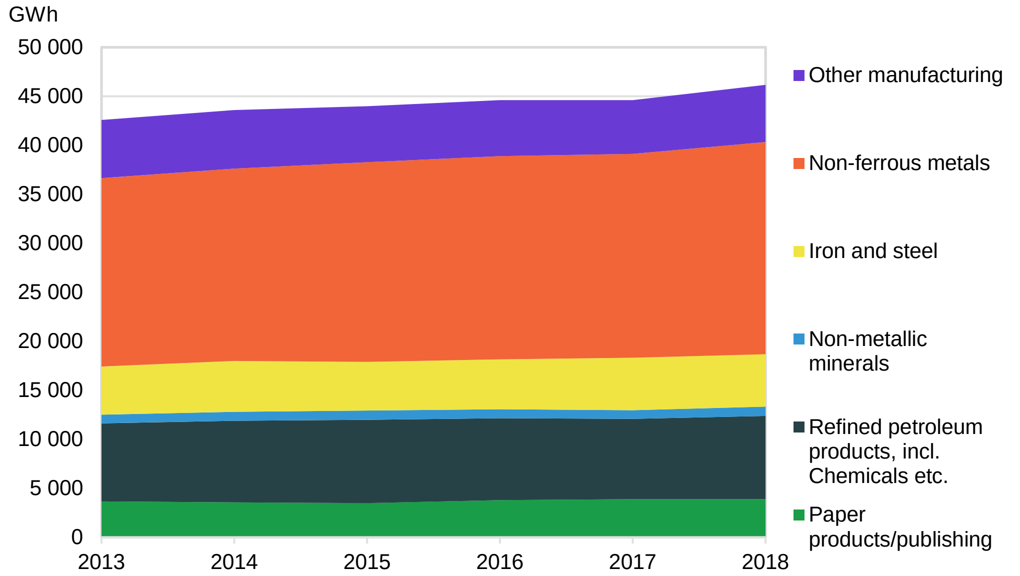
Figure 1 **Output at basic prices in the PII[2] and other manufacturing sectors**



Over the period 2013-2018 the share of the manufacturing industries' electricity consumption of total electricity use was around 40 per cent. Figure 2.2 shows that the PII constitute around 86 per cent of the manufacturing sectors' power consumption, or about 40 TWh in 2018 (Statistics Norway, 2019b). This means that the PII account for a large share of final electricity consumption in Norway.

[2] Manufacture of Paper and paper products (part of PPP), Cement, lime and plaster (part of NMM), Chemicals (part of OIL), Iron and steel (I_S) and Non-ferrous metals (NFM).

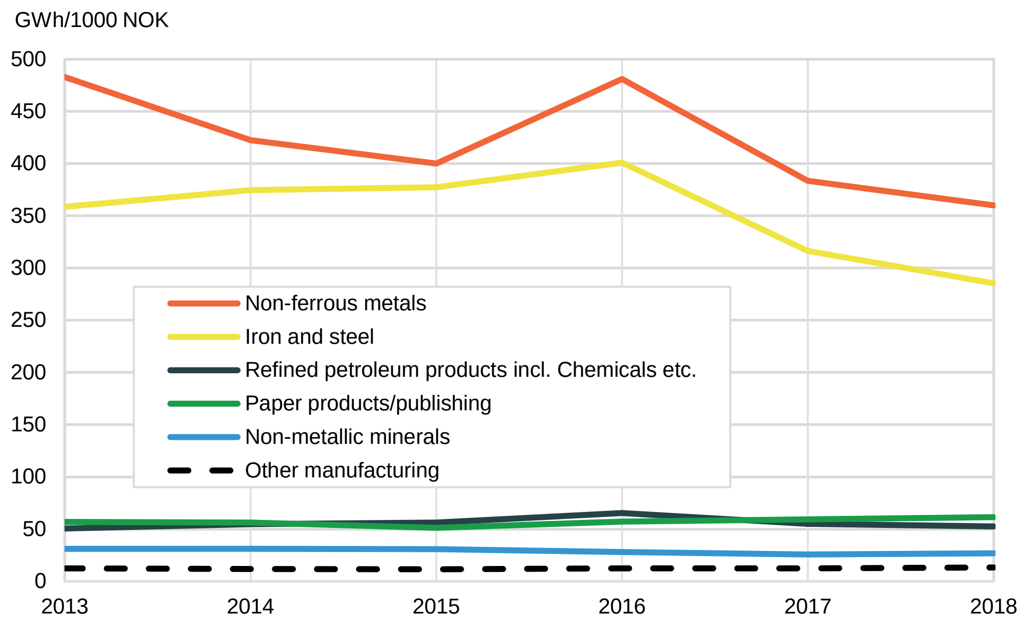
Figure 2 **Electricity use in various manufacturing sectors**



The PII have increased their power consumption with around 10 per cent from 2013 to 2018. Among the power-intensive sectors in 2018, NFM accounts for about 53 per cent of total electricity consumption and OIL constitutes 21 per cent (where the subsector Chemicals uses as much as 17 per cent alone). The I_S, PPP and NMM accounts on average for 14, 10 and 2 per cent of total PII consumption of electricity.

Power intensity can be measured as electricity use in relation to basic value of production as is shown in Figure 2.3. We see that power intensity is highest in the NFM and I_S sector with an average intensity over the period of around 420 and 350 (GWh/1000 NOK), respectively. While OIL and PPP generally has a power intensity that is almost 5 times higher than other manufacturing, the power-intensity of NMM is more than the double of other manufacturing. However, some subsectors of these highly aggregated industries are much more power-intensive as we have already mentioned. Barring the publishing part of PPP, Paper production has an average intensity of somewhat less than 300, while Chemicals in the OIL sector has an intensity of around 220. While total NMM has the lowest intensity of around 30, Cement, lime and plaster part have an average intensity of almost 90. We will comment on the development of the power intensity of the NFM and I_S sector in Section 5.2.1.

Figure 3 **Power intensity (electricity use in relation to basic value of production) in various sectors. GWh per 1000 NOK. 2013-prices**



Model description

The SNOW model for the Norwegian economy (SNOW-NO) is a recursively dynamic numerical general equilibrium model (for a description, see Rosnes et al, 2019). The model can be used to project the Norwegian economy from a calibrated base year (2013) to an equilibrium in each year ahead by choosing values of parameters. The model's data base is the National Accounts (by input-output tables) and emissions accounts from Statistics Norway. In SNOW-NO, Norway is modelled as a small open economy with extensive trade, while the rest of the world is modelled exogenously. The model has among other things been used for studying effects of residential energy efficiency improvements in Norway (see Rosnes et al., 2017).

In SNOW-NO the economy consists of households, companies in various private, governmental and municipal industries and a public sector. Households and companies are modelled as representative participants in the economy. Households receive all income from the primary factors: labour, capital and natural resources. The public sector receives all tax revenues and pays subsidies to industries and transfers to the household. The recursive model is a series of static models that are linked each year via household savings decisions and companies' investment decisions.

There is one representative company in each industry that minimizes costs subject to a technology constraint in each period. There are 46 industries (including the PII); each industry produces one commodity. The production technologies are modelled such that capital, labour and various intermediate input goods (including energy products) to some extent are substitutable with each other. The demand for input factors follows from the cost minimization by the companies. For a description of the production and consumption of energy (e.g. electricity), see Lindholt (2019).

Labour and capital are mobile between domestic industries. There are three types of capital (building and construction; machinery and equipment; means of transport). The amount of capital flow is given in the base year and then developed in line with domestic investment, which in turn is determined by the savings of the consumer in each period. Because households endogenously determine how much they shall work and how much they shall enjoy leisure, labour quantity is endogenous in each period. As there is no sluggishness in the model, labour and capital can instantly move from one sector to another, e.g. to a more profitable one.

All goods consist of substitutable imported and domestically produced variants (e.g. a NFM good). The heterogeneity between domestically produced and imported variants depends on the substitution elasticity. Similarly, production consists of one variant for export and one for the domestic market and the amount of export is determined by export transformation elasticities (as well as exchange rates and market prices).

World market prices are exogenously given, e.g. the price of NFM goods. Factor prices and prices of domestic deliveries are all determined by the equilibrium in the domestic market. Together with a given balance of payments, the real exchange rate that is consistent with domestic consumption will be determined. All prices are real prices, since the model has the consumer price index as numeraire.

Electricity price scenarios towards 2030

The electricity price that the PII face can be regarded as the result of bilateral contracts between the PII and the power companies. Almost all long-term contracts were terminated in 2006-2010 and the firms in the industry had to enter into commercial contracts instead of favourable governmental contracts (Andersen, 2015). Moreover, in some sectors the PII also produce their own electricity. However, the share of own production of total electricity use is only 4 per cent in Chemicals (part of OIL), which is the sector with relatively highest self-production.

We apply various future electricity prices towards 2030. In addition to a reference electricity price, NVE (2018)[3] presents a low and high price scenario as from 2020. We implement these electricity price scenarios in the SNOW model and study the effects on production, export, employment and CO_2-emissions of the PII. We will also take a short look at the effects on other selected sectors, above all households.

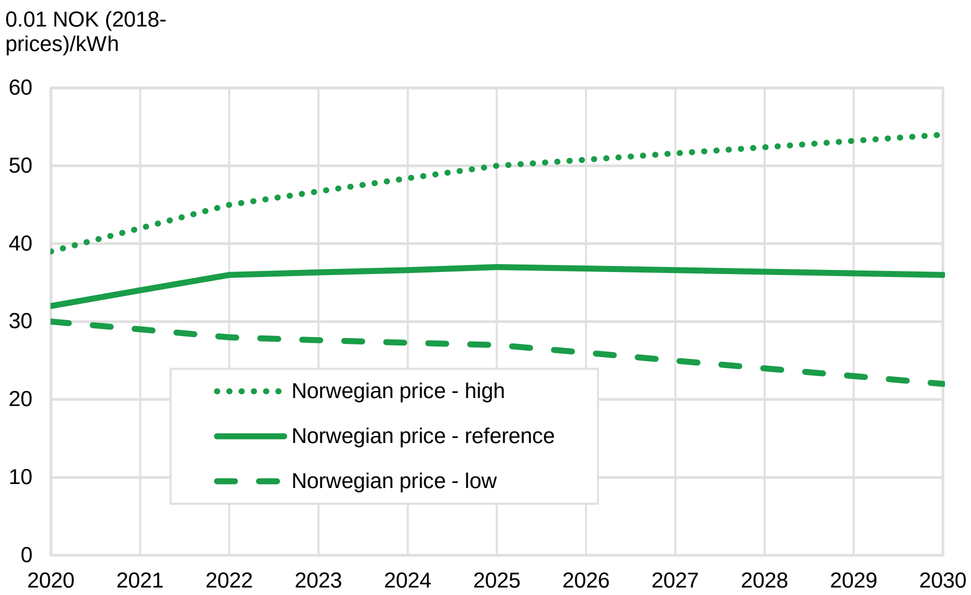
In addition to apply a Norwegian electricity price, we construct an average European power price, which is exogenously inserted in the model. The European price is an average of the various electricity prices in European countries, where we use planned transmission capacity (Statnett et al, 2018) from Norway to these countries for the next decade as weights. I.e., we assume that the trade volumes between Norway and individual European countries are proportional to the transmission capacity. This is done for the reference, high and low price scenarios.

We see from Figure 4.1 that in the reference scenario the Norwegian electricity price increases by around 13 per cent up to 2022 and that it is almost constant thereafter. The reference price is linked to both new cables and increased prices of CO_2-quotas. In the

[3] The electricity price which is applied in the report in 2017 and 2018 is only around 3 per cent lower than the prices in the contracts connected to the spot price for the PII (Statistics Norway, 2019c).

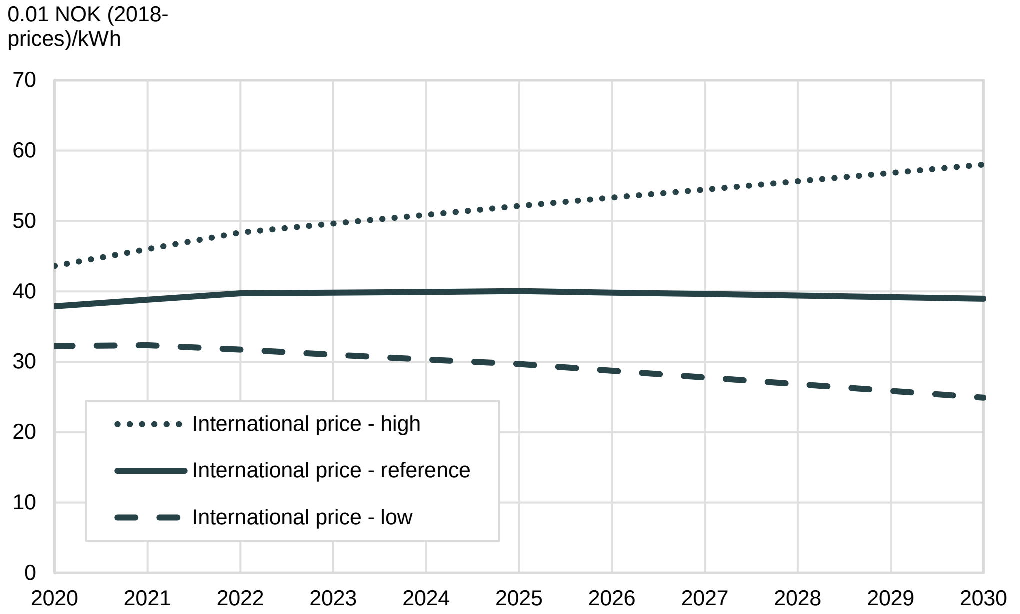
low price scenario, the power price declines on average by over 3 per cent per year over the period such that it is 40 per cent below the reference price in 2030. The low price scenario is not well founded as the quota price is simply set low and constant. In the high price scenario, the price increases by a yearly average of more than 3 per cent such that the price towards the end of the projection period is 50 per cent over the reference price. The high price scenario reflects higher CO_2-prices in the EU to phase-out fossil power production. Regarding the future electricity price, Nordic Energy Research - NER (2016) looks at the most cost-effective way to achieve a carbon-neutral pathway in the Nordic countries by 2050. The electricity price in Norway in their report in 2030 is very close to the high electricity price in 2030 in Figure 4.1.

Figure 4 Norwegian electricity price assumptions. 2018-prices



The international electricity price follows relatively closely the development of the Norwegian electricity price. However, the international price is 0.03-0.04 NOK above the Norwegian one in all three scenarios as is shown in Figure 4.2.

Figure 5 International electricity price assumptions. 2018-prices



The Norwegian power-intensive industries towards 2030

Scenarios without energy efficiency improvements

As a starting point we look at a situation without electricity efficiency improvements in the PII. This means that the sectors must use the same amount of electricity over time to produce the same amount of output, as there are no efficiency gains. This may not seem very realistic, but it can nevertheless serve as a starting point for the analysis. In Section 5.2 we look at scenarios with increased electricity efficiency in the PII. Figure 5.1 and 5.2 shows the effects on output in the different electricity price scenarios. We apply the future reference, high and low electricity prices for both Norway and Europe. As is shown in Figure 2.3, the PII are highly dependent on electricity. There are relatively small substitution possibilities with other energy goods and they are highly export-exposed and must take the world manufacturing product market price as given. As expected, Figure 5.1 shows that a higher (lower) electricity price leads to lower (higher) output in NFM and I_S over the next decade.

In the reference electricity price scenario with no electricity efficiency gains, the output of NFM declines somewhat towards 2030. This is also the case for the I_S sector as Figure 5.1 shows. The main reason why we have declining production is that the reference electricity price in both Norway and Europe is increasing, albeit slowly. Further, in our reference path there is a small (endogenous) strengthening of the NOK over the period. That is, income from export (in NOK) of NFM and I_S goods slightly declines and slightly reduces output over time.[4]

Table 5.1 shows that in the high price scenario accumulated output in NFM and I_S declines by 26 per cent and 21 per cent, respectively, over the projection period from the reference electricity price scenario. Production declines relatively more in NFM because it is relatively more power-intensive than I_S (see Figure 2.3).

Further, as Figure 5.1 shows, they gain from lower electricity prices as both sectors are highly power-intensive. We see from Table 5.1 that in the low price scenario accumulated output in NFM increases by 52 per cent and in I_S by 36 per cent over the projection period from the reference electricity price scenario. The reason why NFM's output increases relatively more with a low electricity price, is again simply that NFM is more dependent on electricity and consequently it will be profitable for this sector to increase production relatively more than I_S.

Figure 6 **Output from Non-ferrous metals and Iron and steel at basic prices. Various electricity prices and no electricity efficiency gains**

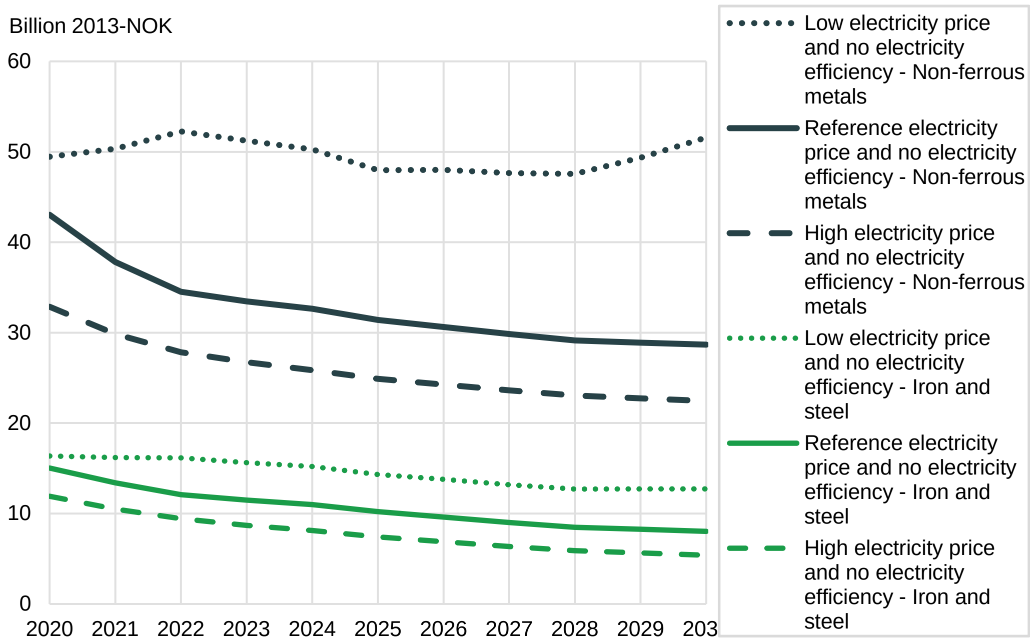
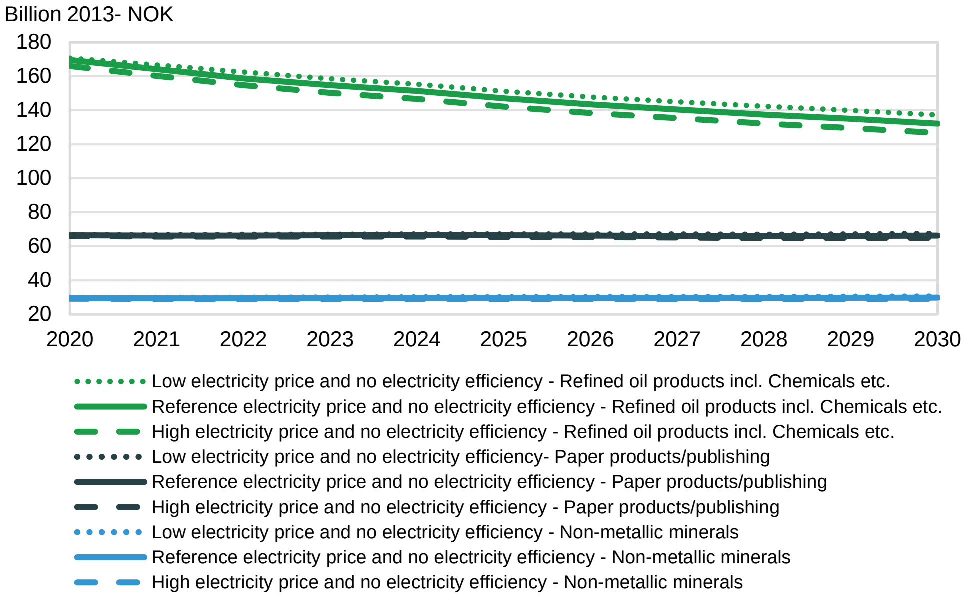


Figure 5.2 shows the output effects for NMM, PPP and OIL. While output is more or less constant for NMM and PPP with the reference electricity price, it declines for OIL. The reason is that the small currency effect (exchange rate increase) is stronger for OIL as

[4] The Norwegian exchange rate is endogenous in SNOW. However, the model incorporates the balance of payment (or current account balance) from the DEMEC model (Holmøy and Strøm, 2017). Hence, the export and import values are determined within SNOW subject to this given balance of payment each year. The DEMEC projection suggests a slightly increasing balance of payment and hence a small strengthening of the NOK towards 2030. That is, a higher NOK makes the domestic products relativity costlier to export and international products relativity cheaper to import. As a result, less is exported and more is imported, and hence we meet the balance of payment constraint. How much each sector exports/imports in SNOW is endogenously determined within the model.

this sector is more export-exposed than the other two industries. As is shown in Figure 2.3, NMM, PPP and OIL are sectors that are less electricity-intensive than NFM and I_S.[5] As a result, the simulations show that the accumulated output of PPP, NMM and OIL over the period is only slightly reduced with a high electricity price. The sectors reduce their accumulated output over the 2020-2030 period from the reference price scenario by -1, -2 and -3 per cent, respectively. In the low electricity price scenario, the industries increase their production by the same relative magnitude from the situation with the reference electricity price. Remember here that we would have much stronger effects if we only were studying the subgroup Chemicals in OIL, Paper products in PPP and Cement, lime and plaster in NMM, as these subgroups are more power-intensive than the aggregated sectors as already pointed out.

Figure 7 **Output from Refined petroleum products incl. Chemicals etc., Paper products/publishing and Non-metallic minerals at basic prices. Various electricity prices and no electricity efficiency gains**



[5] The OIL sector is less electricity-intensive than the other sectors but is highly energy-intensive due to its large use of oil and gas.

Table 2 Yearly change in electricity prices and total accumulated output 2020-2030 in various power-intensive industries without electricity efficiency gains. Change from reference electricity price scenario

		Change in accumulated output 2020-2030 without electricity efficiency growth from the reference electricity price scenario				
Electricity price scenario	Yearly percentage change in electricity price 2020-2030 (2018-prices)	Non-ferrous metals	Iron and steel	Refined petroleum (incl. chemicals etc.)	Non-metallic minerals	Paper/paper products
High price						
International-	3 %					
Norwegian-	3 %	-26 %	-21 %	-3 %	-2 %	-1 %
Low price						
International-	-3 %					
Norwegian-	-3 %	52 %	36 %	3 %	2 %	1 %

Scenarios with energy efficiency improvements

Effects on production

In the following we concentrate on the NFM and I_S sectors. Have the NFM and I_S sectors experienced electricity efficiency improvement in the past, i.e., can they produce the same amount of output with less electricity than they did before? We see from Figure 2.3 that electricity use relative to output (in 2013-prices) for both sectors generally declined from 2013 to 2018. The yearly decline is 4.5 per cent for I_S and 5.7 per cent for NFM. However, we cannot conclude that such a development only stems from technical autonomous electricity efficiency improvements. Firstly, the output values have been deflated with an *average* manufacturing price index, which may have a different development than the product prices of the two individual PII. Secondly, the decline in electricity use per output could be partly due to structural shifts in production over time towards subgroups that use less electricity. Thirdly, a reason may be that the electricity price was higher in 2018 than in 2013, and that this has led to lower electricity use. Finally, there might have been substitution effects towards other inputs (as capital, labour or other energy goods than power, e.g. natural gas) and that this (in isolation) has contributed to increased production. Statistics Norway (2013) tries to isolate the effect of energy efficiency from other effects, e.g. structural effects, and finds an energy efficiency improvement in Norwegian manufacturing of somewhat over 2 per cent per year over the 2003-2012 period. Likewise, IEA (2019) assumes a global average energy intensity improvement of around 2 per cent per year in their reference scenario from 2018 to 2030. To conclude, we do not know about the size of possible efficiency gains in the future for the Norwegian PII. However, based on the discussion above, we introduce 2 per cent efficiency gains per year, i.e., output can remain stable with two per cent lower electricity use per year over the projection period in both sectors.

We see from Figure 5.3 and 5.4 that introducing autonomous electricity efficiency gains increases output in both sectors over the period. Accumulated output in NFM increases by 40 per cent and in I_S by 34 per cent in the reference price scenario from the situation with no efficiency gains. We see that production in NFM in this alternative is relatively constant over time in the reference electricity price scenario (even if the electricity price is increasing as shown in Figures 4.1 and 4.2). Annual production declines by 4 per cent in the reference scenario without efficiency gains, while introducing electricity efficiency gains leads to a relatively constant annual production. This means that output of NFM increases by around 4 per cent annually when we have efficiency gains compared to the situation without gains. If one used the same amount of electricity, the efficiency gains (in isolation; i.e. barring substitution effects) imply that output could be increased by 2 per cent per year.[6] Hence, the relatively large increase in output of 4 per cent per year means that we end up using relatively more electricity in NFM even if power has become more efficient in production. Since the electricity cost share is high in NFM, this "output" effect is large. The same effect takes place for I_S as this sector also consumes relatively more power when we introduce electricity efficiency gains. Further, electricity efficiency gains imply that electricity has become relatively less costly compared to other inputs and there is a (small) positive substitution effect towards the less costly input which is electricity.

As both sectors are highly power-intensive, output declines in the high electricity price scenario from the reference price situation. Accumulated output declines by 36 per cent and 32 per cent in the NMF and I_S, respectively, as Table 5.2 shows. Because both sectors use more electricity per value of output in the reference price case compared to the situation without efficiency gains, introducing the high electricity price has a larger effect on production for both sectors. Again, because NFM is relatively more power-intensive than I_S, introducing higher electricity prices leads to relatively larger decline in NFM's output. In addition, our results show that the substitution possibilities are marginally higher in I_S, so this sector can substitute small amounts of expensive electricity with other inputs.

The fact that NFM is more power-intensive is even more evident when we introduce the low electricity price. Then accumulated output increases by 76 per cent and 18 per cent for the NFM and I_S industries, respectively. Again, because I_S is less power-intensive than NFM, they gain relatively less from lower electricity prices. However, it could be less reasonable to assume electricity efficiency improvements in a low electricity price environment, as the firms then may be less geared towards reducing costs. The huge increase in output in NFM over the projection period we see in Figure 5.3 is therefore less realistic. We could have reduced output by lowering the export transformation elasticities (see model description), which would make it costlier to export. This would have a relatively larger negative effect on the output of NFM because this sector is more export-exposed. However, in a situation with a low electricity price, the effects in the scenarios with no electricity efficiency is probably more reasonable. Table 5.1 shows that accumulated output increases by 52 per cent in NFM and 36 per cent I_S in the low price scenario from a situation with a reference electricity price. In Section 5.3 we ignore the low price scenario when we look at the effects of higher world export prices.

The SNOW model use values from the National Accounts. However, we would also like to follow physical energy flows in simulations of the model. For a description, see Table A1 in Appendix A and the corresponding text, taken from Lindholt (2019).

---

[6] Actually 1.00/0.98 per cent = 2.04 per cent.

Figure 8 **Non-ferrous metals output at basic prices. Various electricity prices with electricity efficiency improvements**

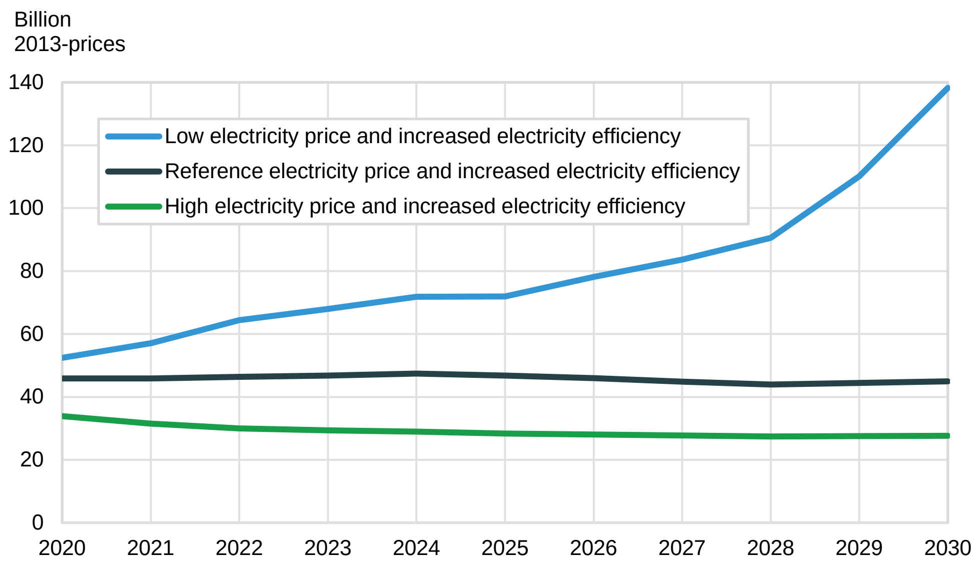


Figure 9 **Iron and steel output at basic prices. Various electricity prices with electricity efficiency improvements**

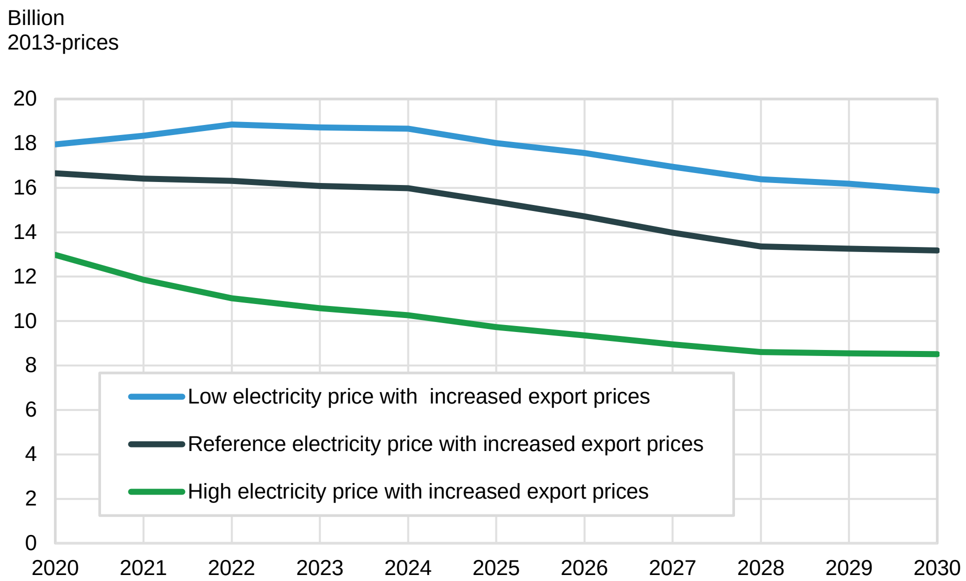


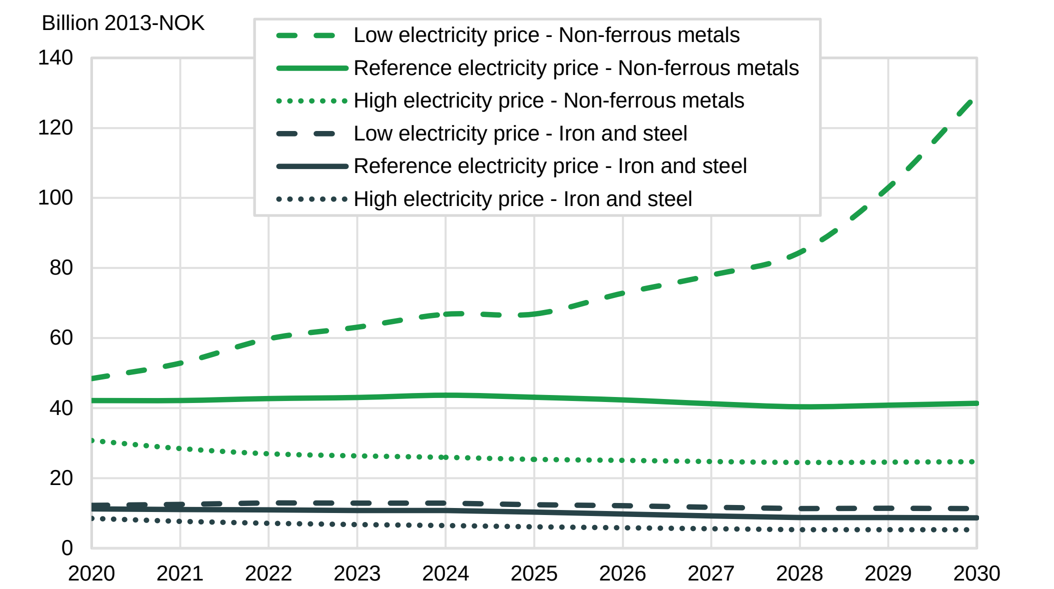
Table 3 **Yearly change in electricity prices and accumulated output 2020-2030 in Non-ferrous metals and Iron and steel with electricity efficiency increases. Changes from the reference electricity price scenario**

Electricity price scenario	Yearly percentage change in electricity price 2020-2030 (2018-prices)	Change in accumulated output 2020-2030 with electricity efficiency growth from the reference electricity price scenario: Non-ferrous metals	Iron and steel
High price			
International-	3 %		
Norwegian-	3 %	-36 %	-32 %
Low price			
International-	-3 %		
Norwegian-	-3 %	76 %	18 %

Effects on export, CO_2–emissions and labour use

Table 5.2 shows that variations in the electricity price have a significant impact on the output of NFM and I_S. Below we present the effects on export, CO_2–emissions and labour use. We see from Figure 5.5 that for both sectors the impacts on export follow the same pattern as the impacts on output. The relative decline and increase in export in per cent over the period from higher and lower power prices, respectively, is not far from the corresponding decline and increase in output. This means that the relative change in total production is distributed relatively evenly on domestic supply and export.

Figure 10 **Export from Non-ferrous metals and Iron and steel. Various electricity prices**



Process emissions are generally around 93-95 per cent of the total CO_2–emissions in these two sectors. Because the process emissions are proportional to production, the relative decline (increase) in accumulated CO_2–emissions from higher (lower) electricity prices is very much the same as the decline (increase) in output as is shown in Table 5.3. The PII account for 21 per cent of the total CO_2–emissions from Norway in 2018. NFM and I_S accounts for approximately 7 and 5 per cent each, respectively. The result is that total accumulated CO_2–emissions decline by 4 per cent in the high electricity price scenario from the reference price case over the next decade. With a low electricity price, the increase from the reference price scenario is around 5 per cent.

The accumulated change in labour use from 2020 to 2030 is also shown in Table 5.3. It follows relatively close to the changes in output. However, the changes are marginally lower in each scenario. The reason is that when the electricity price is high, the relative labour decline is marginally smaller than the output decline (both relative to reference scenario), because we substitute to a small extent towards non-electricity input including labour. On the other hand, when the electricity price is low, labour increase would be marginally smaller than output increase (relative to reference scenario), because we see a small substitution effect towards electricity.

Table 4 Change in accumulated emissions and labour use 2020-2030 from the reference electricity price scenario in Non-ferrous metals and Iron and steel

Electricity price scenario	Yearly percentage change in electricity price 2020-2030 (2018-prices)	Change in accumulated emissions and labour use 2020-2030 from the reference electricity price scenario (in million tons for CO_2 and value of labour use in 2013-prices)				
		Non-ferrous metals (CO_2)	Iron and steel (CO_2)	Total CO_2	Non-ferrous metals (labour)	Iron and steel (labour)
High price						
International-	3 %					
Norwegian-	3 %	-36 %	-32 %	-4 %	-34 %	-31 %
Low price						
International-	-3 %					
Norwegian-	-3 %	76 %	18 %	5 %	72 %	17 %

Effects on other sectors

Electricity is delivered to many sectors and final uses. See Figure A1 in Appendix A and the corresponding text for an overview of the deliveries in 2013 (which is the calibration year of the SNOW model). However, even if the value of the electricity deliveries to a sector is high this does not necessarily mean that the sector is power-intensive. As e.g. other manufacturing industries is less power-intensive than PII (se Figure 2.3), the effect of variations in the electricity price on most of these industries is smaller.

Table 5.4 shows the two sectors, besides the PII, with the relatively highest decline and increase in accumulated output over the projection period from variations in the electricity price.[7] In the sector Motor vehicles and parts the decline in accumulated output is 21 per cent and the increase is 11 per cent from higher and lower electricity prices over the next decade, respectively, compared to the reference electricity price scenario (when we do not assume electricity efficiency gains). The corresponding numbers for the sector Metal production is a decline of 6 per cent and an increase of 6 per cent. However, the changes in bn NOK is higher than for Motor vehicles and parts because the output in NOK in metal production is generally more than six times higher over the period.

[7] In Figure A1 Motor vehicles and parts and Metal production is part of the sector Metal products etc.

Table 5 Change in accumulated output 2020-2030 from the reference electricity price scenario

Sector	Output at basic prices in 2020 (2013-billion)	Change in accumulated output 2020-2030 from the reference electricity price scenario	
		High price scenario	Low price scenario
Motor vehicles and parts (MVH)	7	-21 %	11 %
Metal production (FMP)	45	-6 %	6 %

Households have a total electricity consumption that is higher in volume and value compared to that of the PII (see Table A1 in Appendix A). Our results show that the accumulated value of household consumption over the next decade will decline by 20 per cent in the high electricity price scenario compared to the reference electricity scenario (without efficiency gains in consumption). Further, with lower electricity prices the accumulated value of household use will increase by 11 per cent. Hence, the relative effects of higher electricity prices are not far from the effects on NFM and I_S. However, households gain much less from lower prices. That has to do with the fact that the PII will increase production relatively more than households will increase their total consumption (or spending) when electricity prices decline. In addition, the result is affected by the spending (budget) share of electricity for household compared to the electricity cost share for the industries as well as substitution possibilities.

Scenarios with energy efficiency improvements and increased export prices

The producer prices of NFM increases on average by almost 8 per cent per year from 2013 to 2018 (Statistics Norway, 2019d). However, according to LME (2019) the producer price of the most important good of NFM, aluminium, has declined from September 2018 until November 2019. It is uncertain how the producer price of NFM and I_S will develop in the future. However, to illustrate the importance of these prices, we introduce an increase in the world market export price of both NFM and I_S of 0.5 per cent in 2020.

By comparing Figure 5.3 and 5.6 and Figure 5.4 and 5.7 we can see that introducing higher export prices increases accumulated output in NFM and I_S by around 10 and 5 per cent, respectively, from the reference electricity price scenario with efficiency gains and constant export prices. The reason why the effect is higher for NFM is because this sector is more export exposed. The NFM and I_S sector exports 92 per cent and 70 per cent of their final output, respectively,

We disregard a win-win situation for the PII where they gain both from higher export prices as well as lower electricity prices. In such a situation output would increase even more than depicted in Figure 5.3 and 5.4. Again, as in the other high electricity price scenarios, output declines over the next decade as is shown in Figure 5.6 and 5.7. We see from Table 5.5 that accumulated output declines by 40 and 33 per cent in NMF and I_S, respectively, from the reference electricity price scenario. Again, because NFM is more power-intensive, higher electricity prices leads to a relatively larger decline in NFM's accumulated output compared to the reduction in I_S. This is also a consequence of the fact that the substitution possibilities are marginally higher in I_S, so this sector to a larger extent can substitute expensive electricity with other inputs.

Figure 11 **Non-ferrous metals output at basic prices. Various electricity prices with increased world export prices**

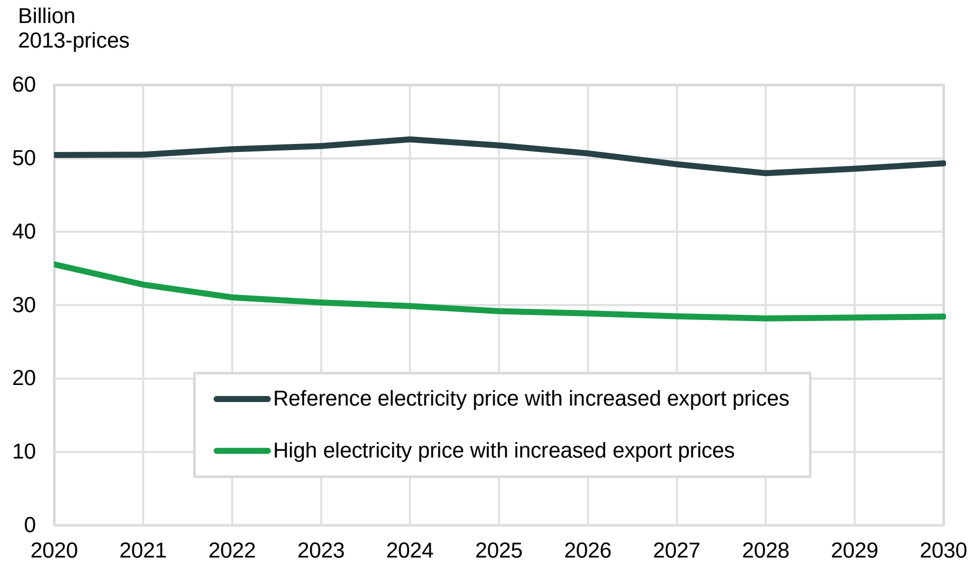


Figure 12 **Iron and steel output at basic prices. High electricity prices with increased world export prices**

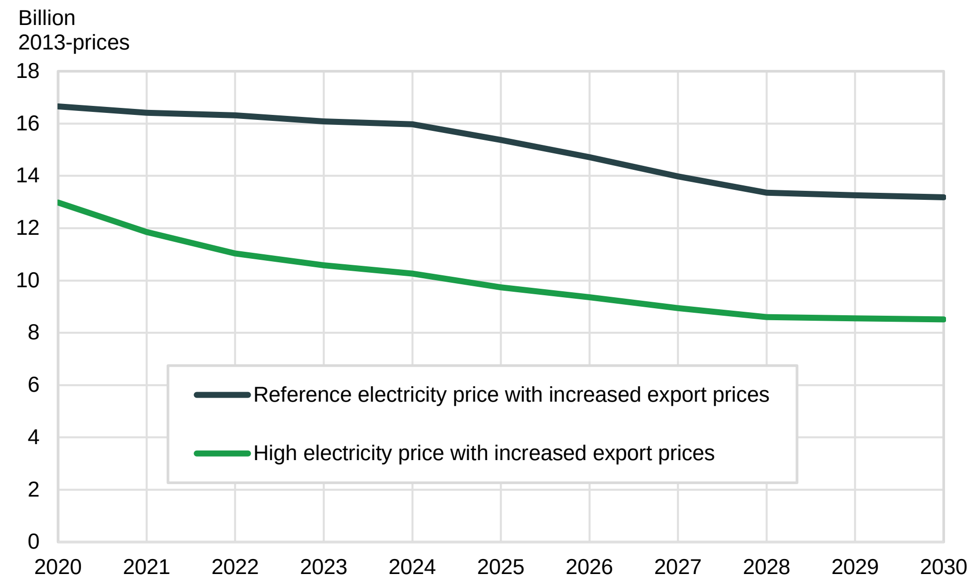


Table 6 **Yearly change in electricity prices and accumulated output in 2020-2030 in Non-ferrous metals and Iron and steel with increased world export prices from a situation with constant export prices**

Electricity price scenario	Yearly percentage change in electricity price 2020-2030 (2018-prices)	Change in accumulated output 2020-2030 with increased export prices from the reference electricity price scenario: Non-ferrous metals	Iron and steel
High price			
International-	3 %		
Norwegian-	3 %	-40 %	-33 %

Conclusion

In this study we simulate the effects of different future electricity prices on the performance of the Power-Intensive Industries (PII) in terms of production, employment, investment and trade over the 2020-2030 period. The PII are large users of electricity as they consume almost 90 per cent of the final electricity use in Norwegian manufacturing. We apply Statistics Norway's SNOW model, a computable general equilibrium (CGE) projection model of the Norwegian economy, with 46 producing sectors (incl. PII) and various household and public consumption sectors.

Our starting point is a reference electricity price scenario. Then we apply a high and a low Norwegian and international electricity price and study the effects on the PII. The PII are highly dependent on electricity. In addition, there are relatively small substitution possibilities with other energy goods in production. Further, these sectors are highly export-exposed and must take the world manufacturing export market price as given. In this study our main focus is on NFM (Non-ferrous metals) and I_S (Iron and steel), the two sectors in Norway that are most power-intensive.

As expected, both NFM and I_S react strongly to variations in the electricity price. In our high price scenario the Norwegian and European electricity prices are around 50 per cent higher than the reference electricity price in 2030. Then the reduction in accumulated output the next decade is 36-40 per cent in NFM and 32-33 per cent in I_S compared to the output in the reference electricity price scenario. The main reason for the larger decline in the production of NFM than I_S is that this sector is more power-intensive.

In our low price scenario, both the Norwegian and the European electricity price decline and the electricity price is around 40 per cent lower in 2030 compared to the reference electricity price. Assuming no electricity efficiency gains in a low price environment, accumulated output over the next decade increases by 52 per cent and 36 per cent in NFM and I_S, respectively, compared to the reference electricity price scenario. Because I_S is less power-intensive than NFM, they gain relatively less from lower electricity prices.

Our results also show that for both sectors the relative impacts on export, CO_2-emissions and employment follow to a large extent the same pattern as the impacts on output.

References

Andersen, B. C. (2015): Empirisk analyse av etterspørselselastisiteten etter kraft i den norske kraftkrevende industrien, Masteroppgave (in Norwegian).

Holmøy, E. and B. Strøm (2017): Betydningen for demografi og makroøkonomi av innvandring mot 2100. Rapporter 2017/31, Statistisk sentralbyrå (in Norwegian).

IEA (2019): World energy outlook, OECD/Paris.

Lindholt, L. (2019): Energy in the SNOW model, Report 2019/22, Statistics Norway.

LME – London Metal Exchange (2019): LME aluminium historical price graph, https://www.lme.com/en-GB/Metals/Non-ferrous/Aluminium#tabIndex=2

NER - Nordic Energy Research (2016): Nordic Energy Technology Perspectives, Nordic Energy Research, OECD/IEA.

NVE - The Norwegian Water Resources and Energy Directorate (2013): Description and economic analysis of energy-intensive industry in Norway, Rapport 69 (in Norwegian).

NVE - The Norwegian Water Resources and Energy Directorate (2013): Analysis of the power market 2018 - 2030, Rapport 85 (in Norwegian).

Rosnes, O., Bye, B. and T. Fæhn (2017): Residential energy efficiency policies: Costs, emissions and rebound effects, Energy 143, 191–201.

Rosnes, O., Bye, B. and T. Fæhn (2019): SNOW model for Norway, Report 2019/1, Statistics Norway (in Norwegian).

Schemde, A., Jenssen, Å., Harsem, s., Gravdehaug, G., Bruvoll, A. and H. Vennemo (2011): Karbonpriskompensasjon - THEMA Rapport 2011-18, Thema Consulting Group og Vista Analyse, (in Norwegian).

Statistics Norway (2013): Increased manufacturing production with less energy (in Norwegian), https://www.ssb.no/energi-og-industri/artikler-og-publikasjoner/okt-industriproduksjon-med-mindre-energi

Statistics Norway (2019a): Production account and income generation, by industry 1970 – 2018, https://www.ssb.no/en/statbank/table/09170/

Statistics Norway (2019b): Production and consumption of energy, energy balance, https://www.ssb.no/en/energi-og-industri/statistikker/energibalanse/aar

Statistics Norway (2019c): Electricity prices in the end-user market, https://www.ssb.no/en/energi-og-industri/statistikker/elkraftpris/kvartal

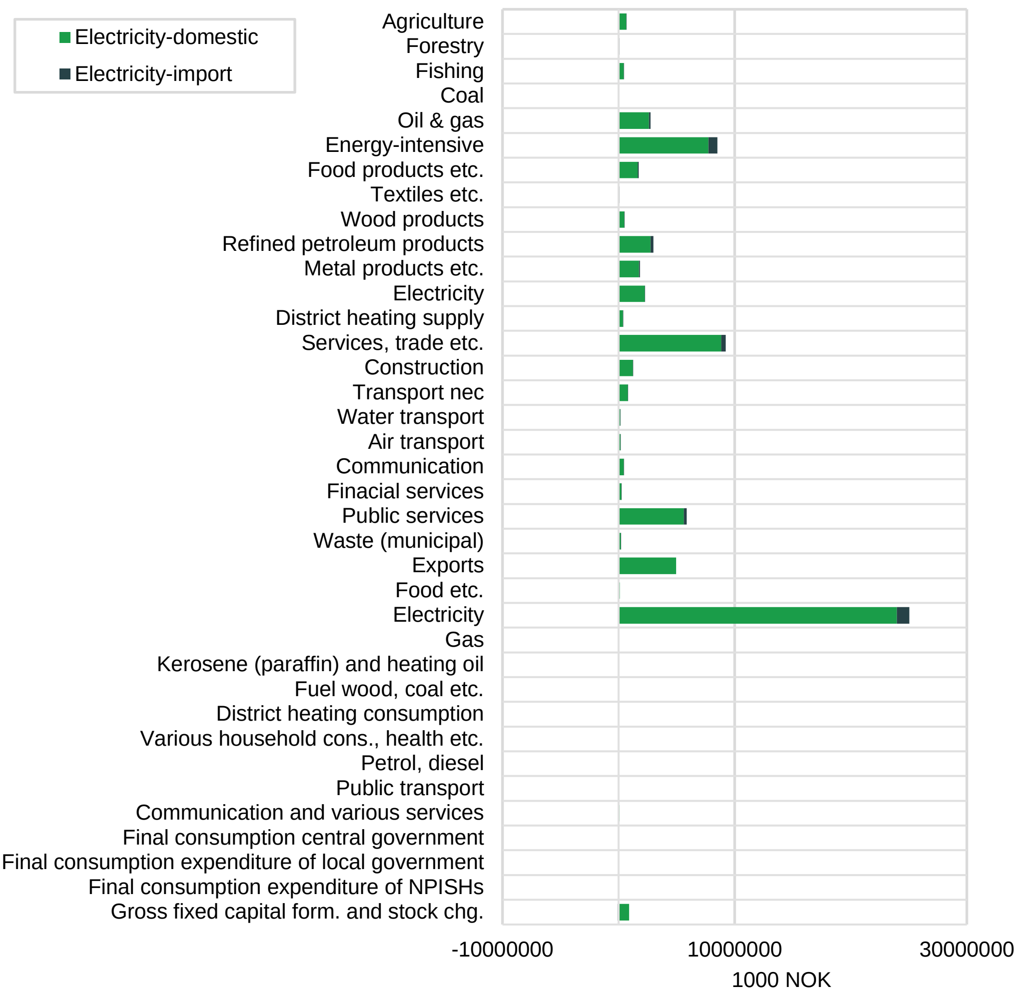
Statistics Norway (2019d): Producer price index. Oil and gas extraction, manufacturing, mining and quarrying and electricity, gas and steam supply, https://www.ssb.no/en/statbank/table/12463/

Statnett, Svenska Kraftnät, Fingrid and Energinet (2018): The Way forward –Solutions for a changing Nordic power system, Nordic grid development plan.

Appendix A: Electricity deliveries to producing sectors and final uses

We see from Figure A1 that the most important electricity deliveries to producing sectors in 2013 go to production of services (9 bn), energy-intensive industries[8] (8 bn) and public services (6 bn). The most important final use sector is household consumption of electricity which amounts to 25 bn (incl. import), and this constitutes 35 per cent of total electricity use. Note that the values do not include taxes and subsidies on products. Electricity is exported for a value of 5 bn, whereas the import value is around 3.1 bn. The two largest importers of electricity are energy-intensive industries (0.8 bn) and household consumption (1.1. bn). The amount of gross fixed capital formation is 0.9 bn NOK, which probably is investment in computer software. The sum over all deliveries to producing and consuming sectors (incl. export) is the total use value. This amounts to 68.7 bn for the electricity sector which is also reflected in the lowest row in Table A1.

Figure A 1 Deliveries from electricity sector to producing sectors and final uses. 2013



[8] Here the numbers are for all energy-intensive industries taken together for ease of exposition.

We have found price figures for electricity deliveries to the energy-intensive industries as well as other manufacturing industries and households. We use the prices and the value figures to get volumes (see Table A1). This makes it possible to follow physical energy flows in simulations of the model for the energy-intensive industries and other sectors. We indicate how we can use the price information for the manufacturing industries to set the prices for other sectors. Hence, we can estimate the volumes also for the non-manufacturing industries (not executed in Table A1).

Table A 1 Domestic electricity deliveries. Value in 1000 NOK, volume in GWH and price in 1000 NOK/GWh (excl. of taxes). 2013

Receiving sector:	Value (1000 NOK)	Price (1000 NOK/GWh)[1]	Volume (GWh)[2]
Agriculture	661 762	357	
Forestry	65 173	357	
Fishing	431 371	357	
Coal	14 211	404	
Oil & gas	2 603 986	404	
Energy-intensive	7 731 529	283	27 326
Food products etc.	1 652 312	532	3 106
Textiles etc.	64 686	621	104
Wood products	487 504	539	905
Refined petroleum products	2 753 259	366	7 512
Metal products etc.	1 771 738	572	3 098
Electricity	2 258 438	344	
District heating	390 725	344	
Services, trade etc.	8 841 204	484	
Construction	1 244 021	344	
Transport nec	785 809	484	
Water transport	123 964	484	
Air transport	170 091	484	
Communication	424 606	388	
Financial services	256 845	388	
Public services	5 617 348	388	
Waste (municipal)	193 109	388	
Total production sector deliveries	38 543 691		
Export	4 945 365		
Final use[3]	25 166 959		
…Of this Households	24 234 337	623	38918
Total use	68 656 015		

[1] Due to lack of data some figures have been set to the average price of other (similar) industries
[2] Lacks reliable data for sectors
3 Incl. government consumption, gross fixed capital formation and stock changes