

NEW 2023: 3

More of everything – faster

The Energy Commission's report

Investigation by a committee appointed by royal decree on 11 February 2022.

Issued to the Ministry of Petroleum and Energy on 1 February 2023.

To the Ministry of Petroleum and Energy

The Energy Commission was appointed by royal decree on 11 February 2022 to survey the energy needs and propose increased energy production, with the aim that Norway should continue to have surplus production of power and that abundant access to renewable power should continue to be a competitive advantage for Norwegian industry. The commission hereby provides its report.

## 1. The Energy Commission's Measures and Recommendations

The Energy Commission's mandate is to examine the long-term perspective of Norwegian energy policy. We have been tasked with mapping out energy needs and proposing increased energy production, with the goal of ensuring that Norway continues to have a surplus of electricity and that ample access to renewable energy remains a competitive advantage for Norwegian industry. Even though our perspective is long-term, we are in a situation that requires swift action and measures that uphold public legitimacy in order to reach these goals. In this chapter, we explain why action is needed now and present our recommendations and proposed measures to bring about a shift in Norwegian energy policy.

### 1.1 The Need for a Shift in Pace

Although the Energy Commission's mandate has a long-term perspective, the direction has already been set through climate targets and the desire to develop new green industries. This direction calls for increased electrification, higher electricity consumption, and new renewable energy production. Over the past year, we have witnessed catastrophic consequences of climate change both at home and abroad, as well as how the geopolitical situation creates significant uncertainty. However, we also see that businesses and industries are ready to tackle new challenges.

If climate goals are to be met, this will require a massive increase in renewable energy. Land transport is set to be electrified, and maritime transport will need emission-free fuels based on renewable electricity. Existing industries that rely on fossil fuels must transition as part of the green shift, and new green industries must be established. We are entering a new era that demands a comprehensive transformation of the energy system, and time is running out. We are no longer just talking about accelerating efforts—we must reach a speed we have never seen before.

We are not acting fast enough. Energy consumption is expected to grow significantly more than current plans for increased renewable energy production can support. In just a few years, we could move from a situation of surplus to a deficit in electricity supply. A reduced electricity surplus will drive up prices, negatively affecting both existing businesses, emerging green industries, and ordinary households. We will become dependent on substantial electricity imports during dry years, and in the event of simultaneous crises and energy shortages abroad, supply security could be at risk.

A new drive is needed, and it must happen quickly. We need more efficient and flexible energy use to reduce consumption, we must stimulate investments in various types of renewable energy to increase production, and we need to expand grid capacity to deliver power where it is needed.

This report highlights the considerable opportunities to improve the situation and the significant potential available. There are numerous tools and measures to increase production and reduce consumption. No single measure will solve the problem—we must utilize all available options.

**At the same time, we acknowledge the challenges. There are understandable reasons why energy expansion has stalled and energy efficiency measures have not been fully implemented. Environmental concerns have made large-scale hydropower expansion unfeasible. Public opposition has led to a complete halt in the development of onshore wind power. The permitting process for both power production and the grid takes a long time, the regulatory framework for solar power, onshore wind, and offshore wind is still unclear, and there are various barriers preventing individuals from conserving energy.**

Additionally, the power sector in Europe is undergoing a massive transformation. In the countries around us, fossil fuel-based power production is being phased out and replaced mainly by variable renewable energy sources like solar and wind. In Norway, the transition will not be as dramatic, but we will still see a significant increase in variable energy production. **More than ever, we need a robust power system—one that can handle crises in a world with more fluctuating energy production both at home and in neighboring countries, and likely greater uncertainty in the coming years than we have seen in the past three decades.**

A dramatic acceleration in renewable energy production, combined with a large-scale transformation of the power sector, makes strong political leadership necessary. Our elected officials must make critical decisions. We will highlight the choices they face, the tools available, the difficult trade-offs that must be made, and how key societal goals can be achieved at the lowest possible cost. There is room for action, and political leadership is needed. We require a strategic approach that ensures a holistic perspective. The time has come for difficult—but crucial—choices. Our ambition with this report is to provide a knowledge base that enables well-informed decision-making.

## 1.2 Climate Goals and the Green Transition: What is Needed?

Measures to reduce greenhouse gas emissions and increase industrial activity suggest that electricity consumption in Norway will continue to rise. Figure 1.1 presents some of the forecasts for future energy consumption growth, with a discussion of the different projections found in Chapter 9.

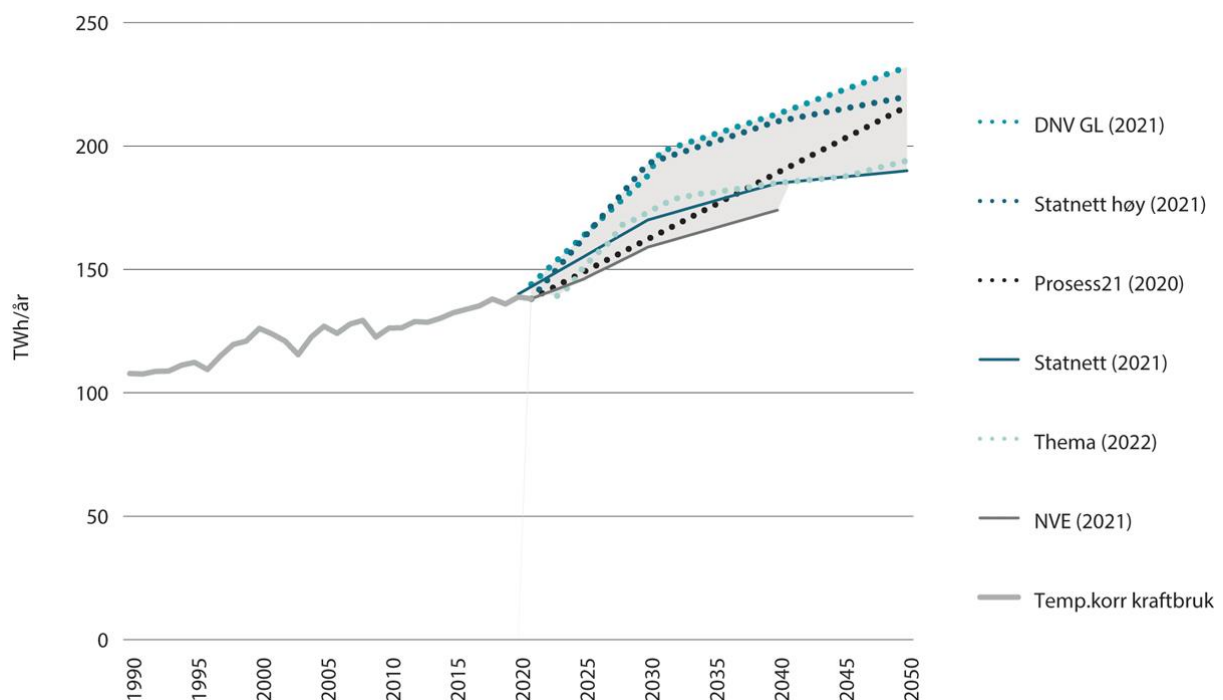


Figure 1.1 Outcome range for projections of power use in 2030, 2040 and 2050, TWh/year NVE (2021), Statnett (2021), Thema and Multiconsult (2022), DNV GL (2021), Prosess21 (2020)

The review of energy usage trends in Chapter 9 shows that energy consumption is expected to grow between 21 and 35 TWh by 2030. Recent forecasts suggest an even greater increase,

with consumption potentially rising by up to 75 TWh by 2030, largely depending on assumptions regarding new green industrial development.

Additionally, the Norwegian Environment Agency has conducted two new analyses indicating that by 2030, electricity consumption could increase by 24 TWh due to the electrification of the industrial and petroleum sectors, and by 44 to 60 TWh in the transport sector by 2050. At the same time, the introduction of a circular economy and limitations on traffic growth may reduce energy demand growth.

These forecasts should not be interpreted as exact estimates of future consumption growth, as there is considerable uncertainty regarding key drivers, such as green industrial expansion. There is also significant potential for energy efficiency improvements, likely greater than what was previously assumed in forecasts made before the recent period of high electricity prices. The energy-saving measures observed due to these high prices suggest that efficiency gains could be substantial.

Norway's power balance is crucial for maintaining competitive prices and securing energy supply. Without expanding power production, Norway's energy balance will weaken. As of the second quarter of 2022, approximately 3 TWh of new production was under construction, with an additional 6 TWh already granted permits (see Chapters 10 and 11). Applications for projects totaling 25 TWh—primarily wind power—were also submitted. However, not all projects will receive permits, and some permitted projects may not be built. In this context, it is essential to accelerate the processing of new projects and increase the permitting pace.

**For the Nordic region as a whole, Statnett estimates that power production will grow in line with consumption, maintaining a net surplus of around 50 TWh. Despite Norway's tight energy situation, the Nordic region could still achieve electricity prices that are competitive in the European market. However, for businesses investing heavily in electrification or green industry, long-term expectations about Norway's energy balance are critical. There must be confidence that Norwegian energy policy will ensure a much stronger power balance after 2030.**

The Commission emphasizes that it is time-sensitive to accelerate energy expansion to move as close as possible to the 2030 climate goals. This requires extraordinary short-term measures. There is no time to handle everything through normal procedures. This urgency aligns with the European Union's current approach to climate challenges and the ongoing energy crisis.

Without new measures, Norway will not achieve its climate goals, facilitate new green industries, or ensure competitive electricity prices. Therefore, strong and immediate action is necessary. Given the need for swift action, we will focus on what can be realistically achieved by 2030.

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### 1.3 Measures for More Efficient and Flexible Energy Use

Climate goals, green growth, and technological advancements shape future energy use. Energy consumption will increase in some areas and decrease in others, affecting all sectors. We will adopt new technologies, transition from fossil fuels to renewables, and construct more energy-efficient buildings. Overall, electricity use will rise.

To maintain a robust energy system, we must optimize energy usage and heating systems, making energy consumption smarter—more efficient, digital, flexible, and responsive to price fluctuations. Improved efficiency and smarter energy use will strengthen the power

balance, ensure supply security, and mitigate the financial impact of high electricity prices on consumers and industry.

### 1.3.1 Action Plan and Governance

Energy consumption is complex, requiring a sharper, more coordinated efficiency policy. Goals and policy instruments must be tailored to different consumption groups and sectors. Therefore, a comprehensive national energy efficiency action plan is needed, ensuring that consumption contributes to supply security. The responsibility for coordinating and implementing this plan must be clearly defined.

The Energy Commission supports clarifying NVE's role in energy efficiency and sees a need for stronger cross-sector coordination.

#### The Commission recommends:

- Developing a **national energy efficiency action plan** with a system-wide perspective, clarifying how efficiency, local energy production, heat sources, and consumer flexibility can contribute to electricity supply security.
- Ensuring the action plan **covers all sectors** and facilitates sectoral integration.
- Setting **clear and measurable targets** for energy efficiency, heating, and flexibility where applicable.
- Including a **comprehensive package of measures** in the plan, ensuring effectiveness by addressing barriers and adjusting existing policy tools.
- **Clarifying the Ministry of Petroleum and Energy's (OED) coordinating role**, as multiple ministries (OED, KDD, KLD, and FIN) manage energy efficiency policies.
- Tasking NVE with **analyzing market trends, regulations, and policy instruments** to recommend appropriate adjustments.
- Requiring NVE to **regularly report on energy efficiency results across all sectors, beyond just buildings**.
- **Expanding Enova's mandate** to cover energy efficiency across all sectors.
- Establishing **clear roles among different policy actors**, with results feeding into parliamentary reviews.

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### 1.3.2 Energy-Efficient and Greener Industry

To ensure energy balance, industry must also become more energy-efficient, flexible, and digital. Energy savings and waste heat utilization in industry can significantly contribute to Norway's power balance.

#### The Commission recommends:

- **Requiring energy management in all industrial enterprises**, starting with energy audits to identify savings and investment opportunities.
- Finalizing and implementing **legislation mandating energy audits** for large businesses (over 5 GWh consumption).
- **Strengthening requirements for energy efficiency and waste heat utilization** through voluntary agreements and economic incentives.

- **Encouraging municipalities to facilitate co-location** of industries that produce and require waste heat.
- Requiring **new industrial projects to assess profitability** of waste heat recovery.
- Considering **stricter energy recovery requirements in emission permits**.
- Establishing **guidelines for municipalities and industrial actors** to optimize waste heat usage.
- Expanding **Enova's support for industrial energy efficiency**.

The potential for industrial energy efficiency remains uncertain, but the Commission estimates a **1–5 TWh reduction in energy consumption by 2030**.

### 1.3.3 National Energy Efficiency Initiative in Buildings

Efforts must focus on **reducing energy use year-round**, particularly in winter, across new and existing buildings. Efficient building envelopes, energy systems, and local energy production will make buildings more flexible, helping consumers adjust to fluctuating electricity prices.

The Commission proposes:

- A **national 7-year efficiency initiative** for residential and commercial buildings until 2030.
- Industry-led **standards for energy solutions**, harmonized with financial incentives and sustainability taxonomy.
- A **competency and information program** for building owners and industry stakeholders.
- A **pilot program for craftsmen** to support homeowners in energy efficiency upgrades.
- **Mandatory energy audits** for high-consumption commercial buildings.
- Revising **building codes** to strengthen energy requirements.
- Expanding **financial support for energy efficiency** in homes and businesses through Enova.

The Commission estimates a **15–20 TWh reduction in building energy consumption by 2030**, compared to 2015 levels.

### 1.4 Measures for District Heating, Bioenergy, and Heat Pumps

Approximately half of electricity consumption in buildings is used for heating purposes. Industry also has significant heating needs. Across the country, local resources can be utilized for heating. If a larger portion of these resources is exploited, it will contribute significantly to power supply security. This will primarily alleviate the power system during winter when demand is highest and electricity prices are at their peak. Local resources, such as district heating based on waste heat, will free up electricity for industrial purposes with high power demands. District heating is often the most efficient way to distribute waste heat from data centers, sewage systems, and waste incineration. Waste heat can be stored in summer and used during seasons with higher heating needs.

The Energy Commission believes that:

- Municipalities must take a comprehensive responsibility for assessing what is the most appropriate heating solution in different areas and take this into account when considering mandatory connection to district heating.
- In areas where district heating is not offered, municipalities must ensure that buildings are designed to accommodate other flexible heating solutions that contribute to strengthening the power and capacity balance.
- Regulations on district heating must safeguard end-users' interests while allowing for innovative solutions in district heating and other heating technologies. These regulations must align with the requirements for flexible heating solutions in the building code.
- The energy labeling system for buildings must be structured so that it does not disadvantage the use of surplus heat and the expansion of district heating.

Members Fredriksen, Hauglie, Lundberg, Sørgard, and Tennbakk believe that developments in technology and the market for local energy production, along with strict energy requirements for new buildings, justify a review of the regulatory framework for district heating. Regulations must be technology-neutral.

The Energy Commission acknowledges that there is considerable uncertainty regarding the potential for increased use of district heating and ambient heat through heat pumps. However, the commission considers it realistic to achieve an increase in district heating of approximately 2-4 TWh by 2030, with the potential to double this by 2040. It also considers it feasible to increase the use of ambient heat through heat pumps by approximately 6-11 TWh by 2030.

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## 1.5 Measures for Increased Power Production

**Even if we utilize the potential for energy efficiency and demand flexibility, more power is needed. Based on currently approved power projects, there is no prospect of significant new production in the short term. Long lead times and low public acceptance are the main barriers preventing a substantial increase in power production in the near future.**

We must address the climate crisis while also tackling the biodiversity crisis. We need to consider multiple sources of new renewable energy while protecting nature and meeting Norway's international commitments. Projects that provide a rapid increase in power production, as well as those that enhance capacity and flexibility, will be most valuable moving forward.

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### 1.5.1 Taxes and Fees Affect the Scope for Development

Tax and fiscal policies must be designed to ensure that profitable investments are carried out while ensuring a fair distribution of tax revenues.

The Energy Commission believes that three overarching principles should guide tax and fiscal policies:

- First, they should be structured in a way that does not hinder economically viable investments in energy production, capacity, and flexibility. To realize more renewable energy, investments in new power production must be profitable for investors. For

instance, to ensure sufficient electricity availability in scarcity situations, it must be economically viable to invest in new power production that can be utilized when market prices are high.

- Second, they must reflect the fact that the power sector utilizes common resources and must contribute to society through special taxation. Hydropower and onshore wind power, both generally profitable technologies, should be subject to neutral taxes that do not discourage investments in renewable power production.
- Third, they must provide predictability. Investments in renewable energy require long-term commitments, meaning that when investment decisions are made, producers must have a high degree of certainty regarding the long-term tax and fiscal framework. The entire power taxation regime should be reviewed and anchored in a broad political agreement.

In addition to these principles, the tax system must consider environmental concerns, including nature restoration efforts.

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### 1.5.2 Hydropower

Regulated hydropower offers great flexibility and will become increasingly important due to significant changes in the energy system, including increased electrification and the expansion of intermittent renewable power in Norway and neighboring countries.

**The least controversial investments involve upgrading existing hydropower plants, such as installing new turbines. Facilities can also be expanded by increasing power capacity, expanding reservoir capacity, or transferring water from nearby watersheds. Such expansions can be controversial and have greater environmental consequences.**

**With highly volatile electricity prices, pumped-storage hydropower may become more relevant. These power plants pump water from a lower reservoir to a higher reservoir when electricity prices are low and use it for generation when prices are high. However, such facilities can be controversial and have significant environmental impacts.**

In line with its mandate, the commission assumes that the current river protection plan remains unchanged.

**A majority of the Energy Commission's members believe that there should be measures to increase the production of regulated hydropower.**

**Member Lundberg argues that modernization of existing power plants should take precedence over new plants and expansions. He believes that large-scale hydropower developments belong in the past.**

The Energy Commission believes that:

- It is important that regulatory frameworks, including taxation, facilitate investments in flexibility, such as increased capacity and pumped-storage power plants.

Lundberg also insists that strict environmental requirements should be imposed on hydropower operations, with national guidelines for power regulation.

The Energy Commission further states that:

- In cases where enhanced flood protection is needed, it should be assessed whether flood protection can be combined with increased power production, provided that unnecessary environmental damage is avoided.



- Small hydropower plants below a certain threshold are exempt from resource rent taxation. This threshold may incentivize suboptimal development, and measures should be considered to address this.
- A majority of the Energy Commission's members believe that during licensing revisions, efforts should be made to avoid the loss of power production and regulation capacity unless absolutely necessary to improve the environmental conditions of watercourses.
- Members Heia, Lundberg, and Ringkjøb emphasize the importance of progressing licensing revisions efficiently, ensuring good local involvement, and improving ecological conditions in watercourses in line with water regulations. This is not only beneficial for the environment but also for license holders. They further argue that this work should be prioritized within NVE (Norwegian Water Resources and Energy Directorate) and OED (Ministry of Petroleum and Energy).

A majority of the Energy Commission's members believe that agreements between the state and power producers should be established to accelerate new hydropower production, ensuring at least 7 TWh of upgrades and expansions by 2030.

The commission estimates that increased hydropower production of approximately 5-10 TWh is realistic by 2030.

### **1.5.3 Onshore Wind Power**

Onshore wind power offers high winter production but is not dispatchable. It is the lowest-cost production technology per kWh and has shorter implementation timelines compared to offshore wind. However, barriers such as environmental concerns, local acceptance, and national legitimacy hinder or delay projects.

To improve local acceptance and legitimacy, several measures are being implemented. Key recommendations include:

- Completing work to give host municipalities more influence in wind power decisions through the Planning and Building Act.
- Exploring the potential for small-scale "near-wind" projects in industrial areas or along major roads, where environmental impacts are lower.
- Ensuring that municipalities benefit economically from wind power developments.
- Encouraging municipalities to proactively plan suitable locations for wind power in their zoning plans.

The commission estimates that increased onshore wind production of approximately 5-10 TWh is realistic by 2030.

### **1.5.4 Offshore Wind Power**

Norway has a significant potential for the development of offshore wind power, see Chapter 10. It is important to clarify the framework conditions and allocate areas for development so that the first projects can be ready for production by 2030.

The Commission believes that:

- It is important to quickly start the development of offshore wind power. Bottom-fixed offshore wind, such as on the Southern North Sea II, is a mature technology, has relatively low costs, and can gradually be developed on purely commercial terms. The first projects will face greater uncertainty and higher costs. They must therefore be offered long-term agreements, such as difference contracts, to mitigate investment risks.
- A long-term and comprehensive plan must be made for the continued development of offshore wind and offshore grid in Norway to provide direction for management, necessary international cooperation, and predictability for the industry. The plan must account for extensive development in the long term, including by:
  - Planning for landfall in Norway in connection with the onshore grid and preparing for a future connection to an offshore grid in the North Sea.
  - Clarifying where development will take place, in what order, and what volume of both bottom-fixed and floating offshore wind should be facilitated.
  - Clarifying key framework conditions such as allocation criteria and processes, pricing regimes, grid costs, and other terms.
- To achieve large-scale offshore wind development, the state must take responsibility for quickly deploying more resources for comprehensive environmental mapping of the Norwegian continental shelf before new areas are opened up. The licensing processes must consider existing data from previous surveys and analyses conducted in other contexts to avoid unnecessary delays in the areas under consideration.
- The development of offshore wind should be facilitated along the entire coast.
- Floating offshore wind, such as at Utsira Nord, has higher costs and is a more immature technology. The first projects will require state support. Projects that can start quickly should be prioritized.
- Difference contracts are a necessary tool in the first phase of offshore wind development. To ensure cost-effective development, difference contracts should be awarded through competition, which has proven successful in the UK.
- In cooperation with labor market parties, an initiative should be taken to enable Norwegian supplier industries to position themselves to win contracts for offshore wind development.
- The majority of the Energy Commission, consisting of members Andresen, Fredriksen, Hauglie, Heia, Ringkjøb, Rollefsen, Seim, Stubholt, Sørgard, Tennbakk, and Tomasgard, believes that the electrification of the continental shelf must be implemented in the most cost-effective way. To meet climate goals, it is crucial that planned projects are initiated quickly, and that started projects do not stop. In connection with existing installations that already source power from land, opportunities for cost-effective offshore wind development should be considered.
- Members Gotaas, Roland, Rollefsen, Seim, Stubholt, and Ulriksen believe that the state should enter into long-term purchase contracts with offshore wind developers. The costs/benefits of these contracts relative to the spot price should be passed on to end users. For bottom-fixed wind power in the Southern North Sea II, this should be directed to consumers on the mainland, while floating wind power from Utsira Nord should serve the oil and gas industry.

- Members Gotaas, Heia, Roland, Rollefsen, Seim, Stubholt, and Ulriksen support electrification of the continental shelf and all ongoing wind power projects. These members believe that to ensure sufficient wind power development and avoid weakening the power balance on the mainland, this should be done in a way that ensures sufficient offshore wind is built over time to meet the energy needs for electrification in the North Sea, and that the cable to land should ensure energy security for these oil and gas installations.
- The majority of the Energy Commission, consisting of members Gotaas, Hauglie, Fredriksen, Lundberg, Ringkjøb, Roland, Rollefsen, Seim, Tomasgard, and Ulriksen, believes that to ensure offshore wind is developed as quickly as possible, it is right to quickly approve the Trollvind project.
- The majority of the Energy Commission, consisting of members Andresen, Gotaas, Heia, Ringkjøb, Roland, Rollefsen, Seim, Stubholt, and Tomasgard, believes that the ambition for bottom-fixed wind development in the Southern North Sea II in the first phase should be increased from 1.5 to 3 GW, in addition to 1.5 GW of floating offshore wind at Utsira Nord.

The Energy Commission believes that there is significant uncertainty regarding both the scope and timing of offshore wind development in Norway. Even if framework conditions are quickly clarified, it is unrealistic that significant amounts of offshore wind will be in production over the next ten years. However, given the areas that have been opened, the goal should be to achieve 5-20 TWh of offshore wind production by 2030.

### **1.5.5 Solar Power**

Solar cells provide the most power production in the spring, summer, and fall, and can contribute significantly to energy security (especially in the spring pinch). The Energy Commission is very positive about the establishment of solar power in Norway, as it can be established quickly, but it is important that the regulations keep pace with this rapid development. This means that barriers must be removed. Current regulations are characterized by threshold values and exceptions that can create suboptimal market adjustments. The current framework is mainly tailored to centralized power production and should be changed to accommodate decentralized power production. In the future, a more comprehensive policy for solar power should be developed, both for building-integrated and ground-mounted solar power.

The development of ground-mounted solar power requires land. Combined uses, such as grazing and solar energy production, can provide better and more efficient land use. Good combination solutions, where various interests are balanced, can often help reduce the level of conflict during development.

For building-integrated solar power, the Energy Commission believes that:

- A strategy for solar power on buildings must be developed, addressing integration into the power market, building permit processes, and technical building regulations for solar power on new and renovated buildings. The strategy should align with upgrading existing buildings and ensure smart integration of solar power into the power system for a rapid and safe phase-in and development.
- The majority of the Energy Commission believes that the strategy must facilitate area solutions and sharing of locally produced electricity and energy storage, where this does not impose significant additional costs on the power grid that must be covered by other customers through grid fees.

- Members Fredriksen, Hauglie, Lundberg, and Ulriksen believe that the strategy should facilitate area solutions and extensive sharing of locally produced electricity and energy storage, as well as the increase or removal of threshold values on system size. Barriers to building-integrated solar power and the consequences for the power grid should be mapped and analyzed.

The Energy Commission further believes that:

- It should be considered to introduce requirements for a share of self-produced energy in new buildings, with exceptions available.
- Exemptions from application requirements under the Planning and Building Act for buildings should be expanded to cover more buildings and solar power installations.

For ground-mounted solar power, the Energy Commission believes that:

- New, innovative land-use combination solutions, such as combining carbon sequestration with solar energy production, should be facilitated. The establishment of such new solutions should be supported by publicly funded research.
- The system for concession applications for ground-mounted solar power must be simplified, and the capacity to process applications must be increased. Consideration should be given to whether municipalities could be delegated authority to approve ground-mounted solar power installations up to a certain size.
- Long-term framework conditions, including principles for future tax regimes, must create predictability and help get development started quickly.

There is significant uncertainty regarding the potential for solar power development over the next ten years. The Commission believes that a development of 5-10 TWh by 2030 is realistic.

### **1.5.6 Nuclear Power**

The majority of the Energy Commission, consisting of members Andresen, Fredriksen, Gotaas, Hauglie, Heia, Ringkjøb, Rollefsen, Seim, Stubholt, Sørgard, and Tomasgard, believes: Nuclear power is not a solution for Norway now, but Norway should continuously follow international developments in nuclear power technology and safety.

## **1.6 Measures for Faster and Improved Case Processing**

Long lead times are a significant bottleneck in the rapid expansion of new energy production and necessary grid capacity. The Energy Commission believes that the licensing process can be streamlined without compromising quality or democratic processes, as discussed in Chapter 10. Licensing procedures must be improved to achieve greater public acceptance and reduce the basis for appeals. The Commission emphasizes that clear political priorities must guide licensing policies. Norway should look to European processes for faster case handling and development to ensure it is not left behind by neighboring countries.

The Energy Commission supports the proposals of the Power Grid Committee and believes that several of these measures can be adapted, strengthened, and applied to the licensing process for new power production. The Commission has also drawn inspiration from the 13 measures proposed by the Norwegian Society for the Conservation of Nature, the Norwegian Association of Local and Regional Authorities (KS), and the Confederation of Norwegian Enterprise (NHO), as discussed in Chapter 10.8.2.

The Energy Commission recommends the following:

- The Norwegian Water Resources and Energy Directorate (NVE) should update licensing guidelines to require project developers to conduct preparatory work and engage with affected parties before submitting notifications and license applications.
- A certification system for environmental assessments should be considered to ensure both high quality and legitimacy.
- A prioritization system should be introduced for application processing, with priority given to projects that contribute significantly to new power production and system flexibility.
- The licensing process should be adjusted based on the scope of the project, with ongoing assessments of whether regulatory procedures can be simplified—particularly for small and non-controversial projects.
- More parallel processes should be established within the licensing procedure to save time.
- It should be assessed whether project developers should take on greater responsibility for early-stage consultations, impact assessments, and hearings.
- Processing deadlines should be set, along with agreed-upon timelines with applicants and requirements for status reporting.
- A coordinated "batch processing" approach should be implemented for multiple applications within a defined area or region where feasible.
- The processing capacity at NVE and the Ministry of Petroleum and Energy (OED) must be strengthened to prevent delays in licensing procedures.
- Requirements for detailed plans for smaller projects and temporary measures should be reduced.
- Appeals against NVE's licensing decisions should be streamlined, especially when the appeal does not contain new, relevant information.
- Authorities must prioritize the development of digital solutions and support systems for licensing processes.
- The time spent by authorities on case processing should be made transparent so that the impact of efficiency measures can be measured, evaluated, and continuously improved.
- Authorities should continually assess and, if necessary, introduce further simplifications in case processing without compromising quality.
- A majority of the Energy Commission, consisting of members Andresen, Fredriksen, Gotaas, Heia, Ringkjøb, Roland, Rollefsen, Seim, Stubholt, Tomasgard, and Ulriksen, believe that the overarching goal should be to simplify and streamline the licensing process for energy and grid development, aiming to halve the processing time.

The Commission affirms that international law, human rights, and indigenous rights must be respected and upheld in energy policy. Developing new renewable energy production requires land use, infrastructure expansion, and environmental interventions. The state has a dual responsibility: to facilitate the energy transition while ensuring the material and procedural rights of indigenous peoples in cases involving environmental impacts. The Commission suggests a broader review of procedural regulations to ensure both the

protection of indigenous rights and the achievement of energy security, climate goals, and power supply needs.

Members Lundberg, Stubholt, and Tennbakk highlight that preemptive construction—allowing projects to begin before the final validity of a license is determined—is common practice in infrastructure development, including in reindeer herding areas. However, such practices can conflict with Article 27 of the UN International Covenant on Civil and Political Rights (ICCPR). The Fosen ruling has shown that allowing construction in reindeer herding areas before a license is legally confirmed is problematic. Further examination is needed to determine whether this practice should be discontinued, as recommended by the Norwegian Centre for Human Rights.

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## 1.7 Measures for Increased Grid Capacity

**The development of the power grid, alongside access to renewable energy, is crucial for achieving the necessary transitions. Grid development must align with national energy goals. The power grid already faces challenges at all levels, particularly in the transmission network. Significant industrial projects and climate initiatives requiring electrification are already constrained by grid capacity limitations. In some cases, there is insufficient capacity for new developments beyond the increase in general consumption. The Commission also points out that the industry has identified grid access as the most significant barrier to new investments (Oslo Economics, 2022).**

The Power Grid Committee has proposed measures to reduce lead times, particularly for large network infrastructure projects, optimize the use of the existing grid, promote more economically rational grid development, and create a more standardized and transparent connection process. The Energy Commission supports these recommendations but wants to go further. The urgent need for increased grid capacity cannot be met solely through better utilization of the existing grid. Grid regulations must be adapted to the current acute need for significant transmission network expansion and allow for long-term planning.

The Energy Commission proposes the following:

- In areas with existing infrastructure where conditions favor increased industrial consumption and power production, grid expansion should be allowed to proceed ahead of concrete consumption plans. Criteria must be established for selecting priority areas and deciding whether investments should be financed through standard grid tariffs.
- The potential for integrating new power production should be mapped in a national capacity overview, as recommended by the Power Grid Committee.
- Criteria should be established to prioritize applications for grid connections based on their societal impact.
- Grid companies should be required to evaluate whether increased network monitoring, combined with consumer flexibility and new technology, can meet demand in place of traditional grid upgrades—similar to measures being introduced in the UK from 2023.
- To accommodate anticipated consumption growth, grid companies should consider taking on more risk by lowering reserve requirements (N-1 standard), allowing them to allocate more capacity to customers without constructing new facilities. Combined

with new monitoring technologies and conditional connection agreements, this could maximize the use of the existing grid.

A majority of the Energy Commission's members believe that:

- Existing grid regulations should be reviewed to provide stronger incentives for grid expansion. Greater emphasis should be placed on proactive grid development rather than waiting for confirmed demand and production before making investments.
- Statnett's mandate should be clarified to ensure that its grid investments align with overarching societal goals and enable proactive infrastructure development.

Member Silje Lundberg points out that the Power Grid Committee's study shows that the pre-construction planning and licensing phases consume the most time in grid projects, rather than the actual construction phase. Therefore, the benefits of building in advance of confirmed demand are limited. Since the main costs of grid projects arise during the construction phase—both in terms of financial expenses and environmental impact—it is more efficient to focus on planning and licensing ahead of time. Conditional licensing could be a solution, allowing construction to proceed more quickly once consumption decisions are finalized.

## **1.8 Organizing for Future Challenges**

The organization and governance of the power sector are crucial for successfully utilizing our shared power resources in a socially beneficial manner. The Energy Commission sees no reason to change the existing division of roles in the Norwegian power sector. This means that the authorities set the framework conditions, while producers and consumers make independent decisions about production, investment, and consumption. We have not conducted a thorough assessment of the organization of power trading itself, but in line with our mandate, we have evaluated experiences with the Energy Act, highlighted the main features of international power trade, and discussed supply security.

### **1.8.1 The Market's Role in the Power System of the Future**

The Energy Commission believes that a market-based system under strong government regulation will continue to manage our water resources effectively. The integration of non-regulatable power sources such as solar and wind power will strengthen rather than weaken the need for such a market-based system (see Chapter 13).

We are now in a situation where we aim for a rapid expansion of power production. This requires framework conditions that enable projects to be financed as cost-effectively as possible and that investments occur at the pace and scale necessary to achieve ambitious goals. The significant and rapid changes required, as well as the expected fluctuations, increase uncertainty for investments. The market alone cannot ensure the necessary transition.

Structural reforms in the power sector are being discussed in both the EU and the UK. One key issue is whether measures should be taken to shield consumers and businesses from extreme price fluctuations.

The Energy Commission believes that:

- To accelerate the expansion of renewable power production, policies and regulations must be adapted to the new situation.
- Consideration should be given to shielding consumers and businesses from major price swings, for example, by facilitating long-term contracts while maintaining

incentives for energy conservation. Lessons should be drawn from the current crisis and the measures implemented.

- Members Heia, Ringkjøb, Tomasgard, and Ulriksen believe that in prolonged energy crises, additional measures may be necessary, such as government financing of peak load to reduce end-user/marginal prices.

The Energy Commission supports the government's planned study of power market pricing. This study should examine:

- Reforms being discussed in other countries, including the UK and EU, and their relevance to the Norwegian power market.
- Whether the current market structure and monitoring mechanisms remain effective in ensuring competition amid the major structural changes brought about by renewable power expansion.
- How to reduce transaction costs in the end-user market.
- Whether and how consumers and businesses should be better shielded from extreme price fluctuations, particularly in general supply.

Member Heia argues that the expansion of renewable energy should be accompanied by mechanisms—whether structural reforms or new political governance tools—that ensure such expansion benefits Norwegian industry and consumers by maintaining acceptable electricity prices, preserving trust in the market and public authorities.

Members Gotaas, Ringkjøb, Roland, Seim, Tomasgard, and Ulriksen believe that climate policies across Europe have made the power sector the most important tool for achieving emission targets. As a result, investment choices are not driven by spot prices but by policy measures. Furthermore, the large-scale expansion of non-regulatable wind power is expected to lead to long periods of very low and volatile spot market prices, making it difficult to invest in new capacity.

A variety of policy instruments are used in Europe to secure sufficient investments in new capacity, including subsidies, green certificates, long-term contracts, capacity markets, and regulations. Extensive studies are underway to determine how the power sector can best be structured to meet emission targets without excessively high consumer and industrial prices.

Members Gotaas, Heia, Ringkjøb, Roland, Seim, Tomasgard, and Ulriksen believe that:

- It is necessary to examine which instruments can achieve the lowest societal cost while ensuring the pace of new power development aligns with climate and green industry goals. Examples include green certificates or long-term state-backed contracts (e.g., balance contracts).

Members Heia, Ringkjøb, Stubholt, and Tomasgard argue that:

- The extreme energy price fluctuations over the past year in Norway and Europe have eroded trust in the power exchange system. These members emphasize the need to establish strong trust between the public and the power system (including the power exchange). If necessary to maintain such trust, public authorities should have sufficient power to safeguard consumer interests, potentially through full or partial public ownership of the exchange.

### 1.8.2 Trade with Foreign Countries

Trade with neighboring countries concerns both supply security and profitability (see Chapters 12 and 13). There remains potential for future economic benefits from power trade.



However, annual variations in water inflow are expected to increase due to climate change (see Chapter 8), meaning that Norway will need imports during dry years.

**It is crucial for Norway to determine whether the power systems to which it is connected will be capable of delivering electricity to mitigate dry-year challenges as neighboring countries phase out thermal power production. Given Norway's unique hydropower-dominated system, it has a different starting point compared to its neighbors when market designs change.**

**The Energy Commission believes that:**

- **Norwegian interests must be clearly defined based on our unique advantages and challenges. Norway should actively participate in discussions on new rules for market design and power trade to ensure a favorable trade regime for Norway, including its consumers and businesses.**
- **Long-term operation of interconnectors should be managed in a way that balances the interests of both parties in a power system increasingly reliant on non-regulatable renewable energy.**
- **A majority in the Energy Commission (members Gotaas, Heia, Ringkjøb, Roland, Rollefsen, Seim, Stubholt, Tomasgard, and Ulriksen) believes that a study should explore how interconnector exchanges can be structured to prevent price contagion from large external power markets from undermining Norwegian energy policy goals.**

The correct dimensioning of interconnection capacity will depend on several factors, including domestic production levels.

**The Energy Commission believes that:**

- **When the concession period for an interconnector expires, an assessment should be made on whether its renewal is in the public interest, similar to the process for new interconnectors.**
- **The need for new cables or hybrid connections should be evaluated in light of Norwegian interests.**
- **The responsibility for interconnectors between Norway and other Nordic countries should be transferred from NVE to the Ministry of Petroleum and Energy (OED) to ensure political accountability.**

**A majority in the Energy Commission (members Gotaas, Heia, Ringkjøb, Roland, Seim, Stubholt, Tomasgard, and Ulriksen) believes that Norwegian authorities must actively engage in dialogue with the EU to ensure that regulations account for Norway's unique characteristics.**

### **1.8.3 Supply Security**

Supply security means ensuring electricity availability at all times, both in terms of capacity (power) and long-term availability (energy) (see Chapter 12). Several of the Commission's proposed measures will enhance supply security, including increased power production and greater flexibility in both consumption and production.

The Commission believes that:

- Regular stress tests should be conducted to assess extreme scenarios, with ongoing forecasts for supply security.

- Hydropower reservoirs are critical to supply security, and regulations must ensure they are managed to maintain a sufficient energy and power balance even in low-inflow years.
- Export limitations must be clarified to protect supply security in extreme situations.
- Stronger incentives for capacity expansion should be continuously evaluated.

A majority in the Energy Commission (members Fredriksen, Gotaas, Hauglie, Heia, Roland, Seim, Stubholt, Tomasgard, and Ulriksen) proposes that:

- Energy security should be explicitly included in the purpose clause of the Energy Act.

### **1.9 The Role of Municipalities**

Municipalities have always played a key role in energy system development and will continue to do so in the future. They are responsible for planning, advising residents, and managing energy use in buildings.

The Commission believes that:

- The social contract between the state and affected communities should be upheld.
- A larger share of wind power revenues should go to host municipalities.
- A national competence center for municipalities should be established to support local energy planning and industry collaboration.
- A majority of the Energy Commission, consisting of members Gotaas, Heia, Ringkjøb, Rollefsen, Seim, Stubholt, Tomasgard, and Ulriksen, believes that the production tax should be secured with index regulation every five years to prevent it from losing its rightful value during the granted concession period, as intended for the host municipalities by the government and Parliament when establishing the production tax.
- The Commission recommends that a fixed share of 15 percent of the state's resource rent tax from each wind power plant should go to the affected municipality that makes its natural resources available for the benefit of society.
- A national competence center for municipalities should be established, and it is natural that it be user-financed. Greater responsibility for power development and efficient, flexible energy use requires competent decision-makers and a platform for knowledge acquisition and experience exchange. A competence center could provide support in the licensing process for new wind power plants, planning and processes related to local energy utilization, ambient heat, surplus heat, co-location of industry and business actors, as well as efficiency improvements in buildings and industry.

### **1.10 The Difficult and Decisive Choices**

Society faces important crossroads. The extent to which we succeed in reducing climate emissions and achieving a green transition is directly determined by how much new power is built and how much more efficient and flexible energy use becomes.

The climate goals for 2030 currently appear highly ambitious. The Energy Commission's message is that how close we get to these goals depends on political will and difficult political choices. Achieving societal goals depends on:

- How successful we are in reducing processing time throughout the entire energy value chain, from production to consumption.
- How effectively we manage to improve energy efficiency across all sectors.

- How much more renewable energy production is developed.

The Commission believes that Norway can build Europe's most robust power system with competitive prices for consumers. We can build on our renewable hydropower system and have other major renewable resources, particularly wind power on land and offshore.

### 1.10.1 Priorities

A key part of the Energy Commission's mandate is to propose measures ensuring that Norway continues to have a surplus of power production at competitive prices. This is particularly important as energy consumption is expected to rise significantly due to electrification in land-based industries, the petroleum sector, and the transport sector, as well as the establishment of new, green, and energy-intensive industries. Electrification is essential to meeting Norway's climate targets for 2030 and 2050, driven by various measures, including CO<sub>2</sub> taxes and emission quotas. The expansion of new green industries is primarily driven by commercial decisions but is also a desired development in line with the gradual phase-out of the oil and gas sector.

The Commission has therefore mapped out potential areas for increased energy production and efficiency measures to meet the growing demand while maintaining a power surplus. Its findings indicate that there is potential for new energy production and efficiency improvements that—if successfully implemented—could meet the projected increase in electricity consumption by 2030.

Energy efficiency measures can provide rapid results. The Commission strongly recommends prioritizing these initiatives as soon as possible. More details on the proposed measures can be found in Chapter 1.3.

However, energy efficiency alone is not enough. That is why the Commission has proposed various measures to increase power production. However, numerous barriers make it challenging to bring sufficient power online in time, including:

- Long lead times in licensing processes for both production and grid expansion.
- Environmental concerns.
- Public opposition to onshore wind power.
- Grid bottlenecks preventing connections.
- Unresolved regulatory frameworks for solar and offshore wind power.

Time is short, and even minor delays could make it difficult to meet the goal of maintaining a power surplus by 2030.

Under its mandate, the Commission has been asked to assess fundamental dilemmas in Norwegian energy policy. If it proves impossible to secure enough power quickly, policymakers will face a difficult choice between three alternatives:

1. **Accepting a temporary power deficit or tight supply**, as projected by Statnett and the Norwegian Water Resources and Energy Directorate (NVE). This would make Norway more dependent on significant electricity imports from neighboring countries and Europe, particularly during dry years, increasing vulnerability to external energy market fluctuations. While there are prospects for a power surplus in the Nordic region overall, periods of tight supply would lead to relatively high electricity prices.
2. **Delaying electrification projects**, such as those on the continental shelf or in other sectors, until power production has increased significantly. This approach could tie electrification efforts to the expansion of offshore wind power. However, it would

likely mean that Norway fails to meet its 55% emission reduction target and the Parliament's requirement to cut offshore emissions by 50% by 2030. Estimates suggest that around 20% of the necessary emissions reductions rely on electrifying oil and gas installations. Similar delays could affect emissions cuts in land-based industries and the transport sector.

### 3. **Restricting the connection of new energy-intensive industries to the power grid.**

This would slow the transition to a green economy. Such restrictions could be implemented by regulating where industries can establish operations based on grid capacity and regional power balance. Allocation of grid access could be based on specific criteria, possibly requiring pre-qualification based on project maturity, or imposing deadlines for project completion. Another approach could be requiring companies to secure energy options that allow for disconnection during critical power shortages.

At this stage, there is no basis for prioritizing among these options, and it is not appropriate for the Energy Commission to make this decision. It is also not necessarily a question of choosing only one option. Various factors must be weighed, and time will tell whether prioritization becomes necessary. Any prioritization will require a holistic approach and must be decided by elected officials. The Commission suggests that the need for prioritization be discussed as part of the proposed regular reporting to Parliament on progress toward societal goals. It is crucial to establish a solid factual basis for decision-making, ensuring that policymakers understand the available alternatives. This awareness will allow for quick policy adjustments while ensuring long-term decisions that guide Norway in the right direction.

## 1.10.2 Direction and Goals

The direction is clear: Norway needs more power to meet its societal goals. This requires:

- Faster implementation of energy efficiency measures.
- Increased investment in renewable energy production.
- Expanded grid capacity.

Stable and competitive energy prices are essential, especially for businesses making long-term investment decisions. Clear signals about long-term energy expansion will give the private sector the confidence needed to invest in new projects.

A majority of the Energy Commission, consisting of members Andresen, Fredriksen, Gotaas, Hauglie, Heia, Ringkjøb, Roland, Rollefsen, Seim, Stubholt, Tomasgard, and Ulriksen, believes that a clear ambition should be set for where Norway aims to be by the early 2030s. The goal for 2030 should be:

- **At least 40 TWh of additional renewable energy production** from hydropower, onshore wind, offshore wind, and solar.
- **At least 20 TWh in energy efficiency improvements.**

If realized, this ambition would ensure ample renewable power, providing a competitive advantage for Norwegian industry and maintaining a net power surplus in a normal year.

However, members Heia, Lundberg, Sørgard, and Tennbakk argue that while the goal should be to accelerate energy production and efficiency measures, external factors may shift over time. Climate policy is constantly evolving, impacting energy policy. Large-scale wind and solar projects in neighboring countries, combined with a favorable trade regime, could

provide Norway with access to cheap electricity in the future, potentially reducing the need for a significant net power surplus. Additionally, onshore wind power expansion may face obstacles, and offshore wind development might be slower and more expensive than anticipated due to environmental concerns or grid limitations. Therefore, it may become necessary to adjust ambitions for new power production accordingly. The key priority now is setting a clear direction, rather than committing to rigid targets that may later prove unrealistic.

### **1.10.3 A Holistic Energy Policy**

Regardless of whether specific targets are set, energy policy should be reviewed regularly, for example, through periodic white papers with a fixed structure. The Energy Commission proposes that Parliament receive regular updates on the overall energy and climate policy landscape. Since climate measures strongly influence electricity demand, energy and climate policies must be closely coordinated. Future developments should be assessed against established scenarios, including extreme weather events, energy savings levels, renewable investment progress, and market conditions.

These periodic reviews should form the basis for adjusting policy tools, such as investment frameworks for renewable energy, measures to modify energy use, and efficiency improvements—similar to how Norway’s National Transport Plan and ocean management strategies are developed. Ensuring energy security must be a key focus.

Because Norway’s power market is closely linked to those of neighboring countries, its energy policies are influenced by international decisions. Therefore, these periodic reviews should also examine how other nations structure their energy systems, whether they provide subsidies, and how regional electricity pricing affects trade.

## **1.11 Overview of the Report**

The Energy Commission was established in February 2022 and will deliver its report in February 2023. The mandate is reviewed and commented on in Chapter 2, which also discusses the commission's work and received input.

The Energy Commission has operated in a situation of high energy prices and war in Europe. This has influenced its work, and an overview of the situation is provided in Chapter 3. This chapter also discusses the studies initiated by the Ministry of Petroleum and Energy in response to the situation.

The Energy Act is a key framework for the energy system. Chapter 4 provides a historical overview of developments leading up to the Energy Act of 1991, the changes introduced by the Act, and other significant decisions that have shaped developments since 1991.

Chapter 5 provides an overview of the current situation: How is energy consumption distributed, and what is the composition of power production?

Climate policy, discussed in Chapter 6, is a key factor in the development of the energy system. Climate policy is driving a rapid shift toward unregulated renewable power production in the countries with which Norway trades electricity. Norwegian climate policy is also increasing demand for renewable power.

The Energy Commission has been tasked with assessing long-term developments. This naturally involves studying long-term analyses of power and energy systems. However, modeling and structured future analysis involve significant uncertainty, as discussed in Chapter 7.

Future developments will result in power systems that are more influenced by weather conditions, both domestically and internationally. Chapter 8 examines how weather variations impact power production.

Numerous small and large decisions will determine future demand for electricity and other energy sources. Many of these decisions are influenced by policies, including industrial policy, climate policy, and energy efficiency initiatives. It is not only important to estimate future demand but also to assess the flexibility of energy users. Future energy consumption and opportunities for energy efficiency are discussed in Chapter 9.

The Energy Commission's mandate includes "proposing increased power production," which involves assessing how much and what type of power production can be realized in the future. Chapter 10 reviews the frameworks and opportunities for new power production.

Chapter 11 examines energy consumption and power production in relation to each other and assesses the potential range of power prices.

A stable supply of energy and electricity is essential for society. Security of supply is both a characteristic of the physical power system and a matter of the framework set for its operation. Chapter 12 presents the Energy Commission's perspectives on energy security.

## **2. The Mandate and the Commission's Work**

### **2.1 Mandate**

The Energy Commission was established by royal decree on February 11, 2022, to assess energy needs and propose increased energy production, with the goal of ensuring that Norway continues to have a surplus of electricity and that abundant renewable energy remains a competitive advantage for Norwegian industry.

The commission was given the following mandate:

\_"Secure access to power is the foundation for value creation and welfare, and it is a necessity for most societal functions today. For decades, access to abundant, clean, and affordable electricity has been Norwegian industry's primary competitive advantage. The government aims to ensure that this remains the case in the future, supporting value creation and employment across the country.

Norway currently has a power surplus in years with average weather conditions. In recent years, significant power production capacity has been added without a corresponding increase in consumption. In the coming years, demand for electricity is expected to grow significantly due to increased electrification, the emergence of new power-intensive industries, and the continued transition from fossil fuels to renewable energy.

The Energy Commission is tasked with assessing energy needs and proposing increased power production to ensure that Norway continues to have a surplus of electricity and that access to renewable power remains a competitive advantage for Norwegian industry.

A key responsibility of the commission is to identify the fundamental dilemmas in Norwegian energy policy leading up to 2030 and 2050, as well as to analyze how different policy choices can impact the long-term development of the Norwegian power supply. These assessments should be based on updated data, including evaluations of the power situation in 2021–2022, the electricity subsidy scheme, and the Power Grid Committee's report.

The commission is expected to maintain close contact with relevant interest groups and professional communities, for example, through consultation meetings, seminars, and other outreach activities. \_"

## **I How Is Norway Affected by Rapidly Changing Energy Markets?**

Norway is increasingly influenced by developments in the surrounding energy markets. Energy and electricity markets in Europe are undergoing significant changes on both the production and consumption sides, alongside rapid technological advancements. These changes will impact electricity prices, energy trade, and the profitability of different types of new power production in Norway.

Based on the evaluation of the 2021–2022 power situation, the Energy Commission will assess how Norwegian energy and electricity supply will be affected in the medium and long term by changes in energy markets. These changes are driven by climate policy goals, technological advancements, and shifts in energy use and production in countries connected to Norway. The commission will assess possible scenarios for future electricity prices in Norway under different assumptions.

The commission will evaluate the experiences gained from the development of the electricity market and energy systems since the introduction of the Energy Act. It will also assess how the objectives of the Energy Act are being followed up. In its evaluation of the electricity market's development since 1990, the commission will examine key aspects of how electricity markets are organized across countries.

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## **II. Perspectives on Power Consumption Development**

The development of Norway's energy and electricity consumption is uncertain and depends on various factors both within and outside the country. Increasing electrification, the transition from fossil to renewable energy, and the establishment of new green industries could drive significant growth in electricity consumption. At the same time, electricity price trends will play a crucial role in determining the costs of using power for new businesses or reducing emissions in various sectors.

The Energy Commission will outline the factors influencing the development of Norwegian energy and electricity consumption today and in the coming decades.

The commission will present and support different scenarios for Norway's future energy and electricity needs, considering factors such as composition, growth, and how various energy policy choices impact demand. It will also evaluate the role of domestic power production and the use of other energy carriers besides electricity.

The commission will assess how different electricity price scenarios (and other cost factors) and the development of the Norwegian economy affect future electricity consumption in industries and businesses. It will specifically analyze factors influencing the establishment of new green industrial ventures, such as data centers, battery factories, and hydrogen production.

The potential for energy efficiency improvements in different sectors will be examined, as well as the role energy efficiency can play in long-term consumption trends. The commission will assess policy measures to unlock this potential, including improving coordination of existing tools and considering the need for new initiatives.

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## **III. Potential for Economically Viable Power Production**

There is still significant technical potential for renewable power production in Norway, provided that electricity prices and regulatory conditions enable profitable development while ensuring acceptable impacts on the environment, landscape, and public interests.

The commission will describe the key factors necessary for unlocking new power production and assess the potential for economically viable new production capacity in Norway. It will analyze the main conflicts associated with new power development and explore possible measures to better address external impacts and ensure local involvement and legitimacy. The commission's work will be based on Norway's Watercourse Protection Plan.

The range of economically viable power production scenarios will be based on different energy policy choices regarding the desired composition and scale of various power sources, as well as electricity price trends, including annual price levels and seasonal variations. The assessment will also consider the costs and opportunities of grid expansion.

The evaluation will adhere to the existing division of responsibilities in the energy sector, where authorities set the framework through licensing and general regulations, while businesses assess the financial viability of power projects.

The commission will determine whether there are measures that could help unlock economically viable power production to reduce the gap between expected consumption growth and power generation.

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#### **IV. Perspectives on Energy Supply Security**

Norway currently has an annual power surplus, significant access to regulated hydropower reservoirs, and transmission capacity that allows for electricity imports during periods of lower inflows. However, the share of unregulated power production is increasing in both Norway and neighboring countries. Rising electrification and higher consumption growth may increase the need for a secure electricity supply throughout the year, particularly during peak demand periods.

Based on the evaluations in Sections I–III, the commission will assess perspectives on Norwegian energy supply security in light of different trends. This includes both annual electricity availability and the ability to maintain balance during critical periods, such as peak winter demand. The commission will examine how electricity crises and high prices in Norway and abroad influence price trends and energy security.

The commission will assess potential measures to maintain energy security and competitive electricity prices for Norwegian industry amid changing conditions.

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#### **V. Key Trade-Offs in Energy Policy**

Using updated insights from the 2021–2022 power situation evaluation and the Power Grid Committee's analysis, the commission will assess major energy policy decisions moving forward and the trade-offs required to ensure a socially beneficial development of Norway's electricity supply in the long term.

The commission will analyze the overall cost trends in Norwegian electricity supply based on different energy policy choices and their impact on end users. It will also explore measures to better balance expected consumption growth with planned production expansion.

##### **2.2 Members of the Energy Commission**

The Energy Commission has consisted of the following members:



1. **Professor Lars Sørgard**, Bergen (Chair)
2. **CEO Øistein Andresen**, Rånåsfoss
3. **Managing Director Bård Folke Fredriksen**, Oslo
4. **Managing Director Sverre Gotaas**, Porsgrunn
5. **Deputy CEO Anniken Hauglie**, Oslo
6. **Mayor Gyro Heia**, Birkenes
7. **Senior Advisor Silje Ask Lundberg**, Oslo
8. **Mayor Hans-Erik Ringkjøb**, Voss
9. **Economist Kjell Roland**, Oslo
10. **Managing Director Gudrun Rollesen**, Hammerfest
11. **Managing Director Helene Seim**, Odda
12. **Partner Liv Monica Stubholt**, Lørenskog
13. **Partner Berit Tennbakk**, Oslo
14. **LO Secretary Are Tomasgard**, Lillestrøm
15. **Managing Director Arve Ulriksen**, Utskarpen

The commission's secretariat consisted of the following individuals:

1. **Håvard Hammaberg**, Senior Advisor, Hafslund Eco Hydropower (Chair)
2. **Toril Johanne Svaan**, Department Director, Ministry of Petroleum and Energy
3. **Monica Skog Jackson**, Advisor, Ministry of Petroleum and Energy
4. **Ingrid Helene Magnussen**, Senior Engineer, Norwegian Water Resources and Energy Directorate
5. **Jan Arthur Sørensen**, Chief Engineer, Norwegian Water Resources and Energy Directorate
6. **Mahi Manus Labråten Pandey**, Vice President, Statkraft
7. **Nora Sundvall Rølling**, Head of Section, Ministry of Finance

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### 2.3 Delimitations and Interpretation of the Mandate

The Energy Commission has been given a comprehensive mandate. The thematic areas of the mandate are clear, but the questions posed are both broad and general. At the same time, the commission was given an unusually short deadline. Initially, the deadline was set for December 15, 2022, but it was extended to February 1, 2023. The broad scope of the mandate and the limited time available have influenced the depth and level of detail in the commission's work.

The overarching objective of the mandate is for the Energy Commission to:

**Assess energy needs and propose increased energy production, with the goal of ensuring that Norway continues to have a surplus of electricity production and that ample access to renewable energy remains a competitive advantage for Norwegian industry.**

This broad formulation of the mandate can be divided into two main components:

1. **Assessing energy needs**
2. **Proposing increased energy production**

The commission has interpreted these key elements as follows:

### **1. Future Electricity Demand is Uncertain**

The future demand for electricity is uncertain, partly due to many plans for large-scale industrial investments. Publicly available long-term market analyses (e.g., NVE, 2021; Statnett, 2020) suggest that Norway may face a structural power deficit in the near future. The commission has examined these projections to outline possible developments in electricity demand. Many organizations have contributed valuable work in this area, and the commission's assessments are based on these studies.

### **2. "Proposing Increased Energy Production" is an Ambiguous Phrase**

The commission understands this to mean that recommendations should be made regarding:

- The types of new energy production that should be facilitated
- How development can be accelerated while minimizing environmental impact and societal conflicts

The government is already conducting extensive work in this area, and the commission has built upon this foundation.

These two main components must satisfy two key criteria:

- **Ensuring surplus electricity production**
- **Maintaining ample electricity supply as a competitive advantage for Norwegian industry**

The commission has interpreted these criteria as follows:

1. **Surplus electricity production** means that, in a normal year, Norway should produce more electricity than it consumes. It is important to specify that this target applies to a normal year because renewable energy production, especially hydropower, varies significantly. If national production exceeds demand, the surplus must either be exported or lost.
2. **Electricity as a competitive advantage** implies that Norway should maintain a sufficient supply of electricity to keep prices lower than in competing countries. Lower electricity prices benefit Norwegian industries by reducing their production costs. The commission understands this goal as requiring sufficient electricity production and a market structure that supports this objective.

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## **Other Considerations**

The mandate includes several additional tasks, but the commission has only commented on those requiring clarification.

The commission's assessments were based on updated data from the **evaluation of the power situation in 2021-2022**, the **assessment of the electricity subsidy scheme**, and the **Grid Committee's report**. These sources were crucial for the commission's work. However, access to these materials was limited until early October 2022, close to the project's deadline.

The **electricity subsidy scheme** falls outside the commission's main mandate, so it has not been discussed in detail. Similarly, the **consumer electricity market** (i.e., electricity sales to households) is not explicitly mentioned in the mandate. There are known challenges in this market, such as misleading or incomplete information provided to consumers regarding electricity contracts. The **Energy Regulatory Authority** and the **Consumer Authority** have jointly proposed measures to address these issues. Given the ongoing work in this area and the commission's tight deadline, the commission chose not to make additional recommendations for the consumer electricity market. Nevertheless, consumer interests were considered, particularly in discussions about demand-side adjustments in the future electricity market.

The commission reviewed the **evaluation of the power situation in 2021-2022** but did not conduct an in-depth analysis, as its focus extends much further into the future. However, the **2021-2022 power crisis was a relevant backdrop** for the commission's work.

The commission has also examined the **Grid Committee's report**.

The mandate requires an **assessment of the range of future electricity prices in Norway under different assumptions**. Given the short timeframe, it was impractical to conduct new electricity price analyses extending to 2050. Instead, the commission reviewed existing long-term market analyses and synthesized their findings to provide a comprehensive picture of possible price developments.

The commission has conducted a **historical review of the Energy Act of 1990**, as requested by the mandate. Since the act had clear goals when it was introduced, the commission primarily focused on assessing whether these goals are still being met. A key consideration was whether the market design ensures **efficient electricity prices that reflect actual costs**.

The commission also assessed **perspectives on energy security**. Many of the criteria related to energy security align with the broader mandate objectives—namely, ensuring that power production in a normal year exceeds consumption. The commission also recognizes that **unusually high electricity prices may indicate anticipated supply shortages**, but it has not specifically analyzed high prices from an energy security perspective.

## **2.4 The Energy Commission's Work**

The Energy Commission was appointed on February 11, 2022, and held its first meeting on March 3. In total, the commission held 13 meetings, including one in Trondheim and one in Stavanger.

The commission's working methods were structured according to the Ministry of Local Government and Regional Development's guidelines for government committee work. The Ministry of Petroleum and Energy assisted the commission with administrative matters, such as procurement assistance and budgeting.

The commission maintained a dedicated website, [www.energikommisjon.no](http://www.energikommisjon.no), providing information on its mandate and committee members. Through this website, the commission also invited written contributions from the public until May 25. These contributions were published and made accessible.

### **Stakeholder Engagement**

The commission was tasked with maintaining close contact with relevant interest groups and expert communities. On May 10, 2022, it hosted an open, digital consultation meeting to gather perspectives and input related to its work. Participants were encouraged to provide input on the following topics:

1. How is Norway affected by rapidly changing energy markets?
2. Perspectives on developments in electricity consumption
3. Potential for economically viable power production
4. Perspectives on energy security
5. Key conflicts in energy policy
6. Other general input

A total of 55 organizations, businesses, and individuals took the opportunity to provide brief input to the Energy Commission.

Additionally, the commission gathered information and held meetings and expert seminars with selected research institutions, interest groups, businesses, organizations, and government agencies as part of its work.

On May 11, the commission held a seminar in Oslo focusing on topics such as new wind power production, European energy policy and Norway's options, licensing processes, markets, nature and the environment, coordination, and electricity prices. The commission also hosted an open meeting during the Arendal political festival.

### **Written Contributions**

By the deadline of May 25, the Energy Commission had received 120 written contributions, evenly distributed between individuals and businesses/organizations. Some contributions were also submitted after the deadline, and all were reflected in the summary.

Several contributions referenced the energy situation of 2021-2022. Many called for a cap on electricity prices in Norway and expressed skepticism about foreign electricity trade. The design of the electricity subsidy scheme, including whether it should cover district heating, was also a recurring topic.

The organization of the electricity market was another major theme. Contributions addressed both domestic market structures and electricity exchange mechanisms. Some proposed dividing the country into more or fewer price zones.

Some contributions argued that the current market structure had served Norway well, as electricity exchange and cross-border cooperation ensure energy security and efficient resource use. Others questioned the benefits of electricity exchange and called for a socioeconomic analysis of its value. There were also specific suggestions, such as integrating more closely with the Finnish power grid.

There were mixed views on long-term power market forecasts. Some referenced studies predicting a significant need for increased production, while others were skeptical of such forecasts.

### **Energy Efficiency and Flexibility**

Many contributions emphasized the need for greater energy efficiency efforts, with several advocating for public funding. Some suggested expanding the mandate of Enova (Norway's energy efficiency agency) to better support private households. Others highlighted building regulations (technical building codes) as an important tool for energy efficiency and suggested that municipalities should be able to set requirements under the Planning and Building Act. Suggested measures included energy-saving obligations and efficiency targets with corresponding reporting.

Some contributors pointed to the benefits of increased flexibility in building heating systems, allowing surplus heat from industries to be used efficiently. Suggested measures included requirements for energy-flexible buildings and financial support for conversion to such solutions. Others proposed technical standards accounting for energy inputs from heat pumps. There were also suggestions to facilitate local energy production and trading.

### **Increasing Energy Production**

Several contributions highlighted the need for increased energy production. Many pointed to specific energy sources that should be prioritized, such as nuclear power, biogas, upgrades and expansions of hydropower, onshore wind power, and offshore wind power. Others advocated for a diverse mix of solutions.

There were multiple suggestions for changes to the licensing process for renewable energy projects, including the introduction of regional cooperation bodies. Those supporting increased renewable energy development argued that the permitting process should be streamlined, for example, by strengthening regulatory agencies. Some also emphasized that clear priorities would help accelerate the approval process, such as setting explicit targets for new power production. Others suggested that key inputs for the renewable sector, such as minerals, should be extracted or produced domestically in Norway.

Regarding wind power, many contributors stressed the importance of learning from past experiences with onshore wind development. Some submissions provided detailed comments on specific aspects of wind power, such as the need for better environmental impact assessments, ownership regulations, reversion (reclaiming wind farms after license expiration), and improved local compensation schemes for host municipalities. Others argued that wind power remains the most cost-effective form of energy production.

For offshore wind, several contributions included specific proposals on how to manage development. Views varied on whether offshore wind should be connected to a North Sea grid or linked directly to national power systems. Some called for public ownership of offshore wind projects. Others opposed large-scale offshore wind development, citing concerns about the need to protect marine environments.

## **2.5 Investigations**

The committee has carried out three investigations. The first report is an analysis of drivers and uncertainty in long-term power market analyses. It is Multiconsult in collaboration with Thema that has carried out the investigation. The investigation looks at how long-term energy market analyses are carried out and which drivers for future development have been identified in the analyses. The investigation also deals with information about uncertainty in the analyses, which areas of use the analyzes are suitable for and what they are less suitable for.

The second report is an analysis of challenges in balancing the power system in the future towards 2050. Thema in collaboration with Multiconsult has carried out the report. In this, an overview is given of the various sources of flexibility in Norway and Europe, as well as a discussion of trends in the supply of and demand for flexibility towards 2050. The study also provides an overview of what affects the power system's ability to achieve balance, both geographically and in time.

The third study analyzes the industry's power needs. Oslo Economics and Sintef have carried out the study. The investigation consists of both a qualitative analysis of which factors are important for the establishment of new industry, and an analysis of which factors influence

the development of energy use in existing industry. The potential for energy efficiency in larger industrial enterprises is also included.

The three reports are attached as digital attachments.

### **3 Energy crisis and war in Europe**

Russia invaded Ukraine on 24 February 2022, and the Energy Commission delivers its report in a situation where there is war in Europe.

The Energy Commission was formally appointed on 11 February 2022, and the mandate naturally does not mention the war. The situation has affected the energy markets in Europe, and contributed to very high power prices in Norway. The war in Europe has formed a serious backdrop for the Energy Commission's work.

Power prices began to rise already in 2021. In the wake of the corona pandemic, we saw a particularly large demand for gas. In Europe, there was a long and cold winter and a lower supply of wind power than usual. At the same time, the price in the CO<sub>2</sub> quota market rose. High gas demand in Asia affected the global gas market, and Russia limited its gas exports from the summer of 2021 to the volumes covered by long-term agreements with European countries. Overall, it contributed to gas prices rising, and thus also power prices (IEA, 2021) (IEA, 2022).

Unfavorable weather conditions have helped to intensify the crisis through 2022. Drought and a heat wave in large parts of Europe have resulted in low inflows to hydropower, problems with transporting coal to thermal power plants and problems with cooling water for nuclear power plants. Backlogs in the maintenance of nuclear power plants have characterized the French power sector.

Europe and Norway have received record high prices for electricity, with major consequences for industry, business and households. The very high prices and the concern for security of supply are two main challenges going forward.

#### **3.1 A European challenge**

With the aim of reaching the climate targets under the Paris Agreement, many of the EU's member states have had intentions to phase out their coal power plants by 2030. Germany, which is an important power producer in Europe, is also phasing out nuclear power. Over time, this has meant that gas has gained a more prominent role as a stable and relatively less polluting energy source in Europe's transition phase. In particular, gas has been important in periods where production from solar and wind power has been low.

In the autumn of 2021, Russia began to reduce its gas deliveries to the EU market. In the last quarter of 2021, delivery fell by 25 per cent compared to last year (IEA, 2022). Sanctions, legal implications and a polarized geopolitical debate about the consequences for energy security had characterized the laying of Nord Stream 2 for a long time, and in autumn 2021 the pipeline project was stopped again. This also led to gas prices rising (European Parliament, 2021). With Russia's invasion of Ukraine in February 2022, we saw a further destabilization of the energy markets, with major energy consequences and increasing unrest.

In 2021, Russia accounted for more than 40 per cent of gas deliveries to EU countries, 27 per cent of oil and 46 per cent of coal (EU Commission, 2022). Over the past year, Europe has lost most of its gas supplies from Russia. This has contributed to the energy shortage and price crisis in Europe. Although it has already been planned to phase out fossil energy sources, gas has been seen as crucially important in the transition period.

It is uncertain how the situation will develop and how it will affect energy prices and the global economy. What has until now been energy policy merges with, and is subordinated to, security policy. The established understanding of what constitutes a reliable energy source and supplier for Europe has changed, and the pressure on the EU to phase out Russian oil and gas imports is great. This has also increased the importance and value of gas from the Norwegian continental shelf.

War is not a permanent state, but it is unlikely that Europe will be able to rely on Russian gas in the future. Therefore, other solutions must be put in place. At the moment, energy policy in Europe is strongly characterized by uncertainty and the search for good solutions that can stabilize the situation. The acute situation must be dealt with and plans must be made to ensure a secure energy supply with acceptable prices in the future.

Reduced gas supply from Russia has initially led to more use of coal and oil in Europe. Planned shutdown of nuclear power plants in Germany is postponed. In the winter of 2022/2023, extensive energy savings are planned. Although Norway has contributed with increased gas deliveries, and Europe has received gas from other countries in the form of LNG, several industrial companies have stopped their production. This may in turn affect the basis for the part of Norwegian industry that supplies the European market. In order to ensure deliveries in the slightly longer term, the EU countries have started significant investments in storage and gasification facilities for LNG. See box 11.1 for discussion of the transition to a more normal situation.

The EU has long had targets for, among other things, hydrogen production, energy efficiency and renewable energy production towards 2030. In the current situation, the EU has chosen to accelerate its energy transition and strengthen its energy policy goals. Reforms of the European energy and power sector and changes in market design are considered. We do not know what the outcome will be and the long-term consequences.

The situation in the gas market has contributed to unacceptably high power prices in all countries, and it has been necessary to introduce electricity support schemes to remedy the situation. Discussions about crisis measures to deal with rising energy prices and ensure security of supply in Europe in both the short and long term characterize the news picture.

What happens in Europe also affects Norway to a very large extent. Our water reservoirs and oil and gas resources are more valuable than ever. But consumers, and those parts of business that do not have fixed-price contracts, have electricity costs that are unacceptable. For many, electricity costs are devastating to the economy.

The Energy Commission's mandate is aimed at 2030 and 2050. The Commission assumes that we will have an energy and power system based on renewable energy sources. The Energy Commission is therefore concerned that good institutions are built, which lay the foundations for efficient utilization of all energy resources and flexibility resources, and which provide good security of supply. It will be difficult to achieve the long-term goals. The acute situation resulting from the war should not lead to decisions being made that reduce the efficiency and security of supply in the system.

### **3.2 Investigations of the power situation 2021/2022**

As a result of the high power prices, in 2022 the Ministry of Petroleum and Energy set out five assignments to investigate aspects of the power situation in 2021/2022. The results of the investigations were presented in Prop. 1 S (2022–2023) for the Ministry of Oil and Energy.

The five studies are briefly summarized here, based on the mention in the state budget for 2023.

## **The impact on households**

Statistisk Sentralbyrå (SSB) has assessed the effects on households of increased electricity prices, and evaluated the support scheme that the Storting adopted in December 2021. SSB found, among other things, that the increased expenses had the greatest negative impact on households with a low income. Households with higher incomes had a larger increase in expenses, but have both a greater ability to pay increased expenses and a greater opportunity to implement energy saving measures. Statistics Norway found that households have had significant energy savings. Statistics Norway also found that the electricity subsidy scheme has had a major influence on households' finances, and has been particularly important for households with the lowest incomes. However, payments for electricity subsidies increase on average across income groups.

## **The impact on the Norwegian economy**

DNV and Vista Analyze have reviewed the effects of high electricity prices on the Norwegian economy. The analysis shows that the increased electricity prices have led to lower power consumption and a lower level of activity in business. Power-intensive industry had a smaller decline in activity than other industries, particularly because in this sector there is widespread use of long-term contracts for power supplies.

## **Financial markets and price hedging**

Thema has reviewed the status of the financial markets in the Nordics with regard to the price hedging options for power suppliers in Norway. They propose a number of measures, which are not summarized here. The Energy Commission has considered the organization of the financial markets to be outside the commission's mandate.

## **The magazine layout**

Sintef analyzed magazine allocation through the autumn of 2021 and the effects of Norwegian power exports. Sintef's report was not available until the Energy Commission's report was completed. The preliminary results are reproduced in the Ministry of Petroleum and Energy's Prop. 1 S (2022–2023).

The producers' decisions about magazine allocation are always made under great uncertainty about future rainfall conditions and prices. The price expectations determine the producers' assessments of the future value of the water in the reservoirs. In the simulations, Sintef found that the magazine allocation largely corresponded to the manufacturers' price expectations. The following observations were made:

- In 2021, the filling rate was reduced from being above average before week 26 to below average and further down towards the minimum filling rate in the statistics until week 38.
- From week 38, the fill rate remained low throughout 2021, despite the fact that the inflow was higher than normal and that production will typically be reduced at a low fill rate. An important explanation is that the European futures prices increased beyond the autumn of 2021 at the same time that the producers expected a normalization further into the future. It therefore appeared optimal to produce a lot even if the magazine filling was low.

Calculations from NVE and other analysis groups nevertheless indicate that in autumn 2021 somewhat more was produced and exported from Norway than the particular price development indicated (Sintef, 2022).

High European power prices and the expectation of normalization of the price picture a little further in time were the most important reasons why there was high production and a lot of exports from Norway in the autumn of 2021.



**Sintef also simulated the development of the power system through week 36 to week 52 in 2021 with and without the transmission cables to Germany and Great Britain. The simulation has been done for 40 different weather years. Sintef found that the cables contribute to raising the power price in Eastern Norway by around 15-25 øre/kWh, equivalent to between 14 and 26 per cent.**

### **Measures in the market**

Afry and Menon Economics have considered measures such as a maximum price in the wholesale market, storage restrictions, export restrictions, development of the network, measures in the end-user market and a model for a state-owned power supplier. The measures aimed at the end-user market are not discussed in more detail here, because they are understood to be outside the Energy Commission's mandate.

### ***Requirements for magazine filling***

One of the measures Afry and Menon have modeled is that a minimum requirement is set for magazines in each price range with a duration from week 40 to and including week 18 of the following year. In the analysis, the minimum requirement for each magazine was set at 10 per cent above the lowest fill rate measured in the last 20 years for each price range.

They found that it will lead to a slight decrease in the price in southern Norway. According to the analysis, the filling rate is higher than without the regulation, and the effect is stronger in southern Norway than in northern Norway. In Northern Norway, they found a slight price increase.

### ***Restriction of power exports***

Afry and Menon have also considered measures intended to limit Norway's exports abroad from southern Norway.

In the analysis, they have halved the capacity between South-West Norway (NO2) and Great Britain, Germany and the Netherlands compared to normal capacity. The import possibilities are not curtailed. They found that the export restriction has a limited effect on magazine filling in southern Norway. The measure resulted in a lower power price in southern Norway, and this effect will be greater if they assume a higher gas price.

In an analysis where the export capacity is set to zero out of south-west Norway (Germany, Great Britain, the Netherlands and Denmark), the minimum magazine filling for all price areas in south-Norway (NO1, NO2 and NO5) will increase. The simulations that Afry and Menon have done indicate that the water loss during the snowmelt could be large without export opportunities from South-West Norway. They found a significant reduction in power prices in all price areas in Norway, particularly in southern Norway in this year with a high influx.

Afry and Menon have also analyzed the impact of an export tax. In a situation with relatively large price differences between the Nordics and Europe, Afry and Menon found that an export tax had to be relatively high to have an effect on trade. The effect of a high tax on exports over foreign connections out of South-West Norway (NO2) is similar to the effect of limiting export capacity, both in terms of price and magazine filling. Afry and Menon consider that export reductions will generally be contrary to current agreements on free trade, but point out that there are exceptions for measures aimed at preventing product shortages. It is important to assess possible reactions from neighboring countries, and how this could negatively affect the security of supply in Norway during periods when Norway has import needs.

### *Maximum price in the wholesale market*

Afry and Menon have assessed the maximum price in the wholesale market. Maximum price means that the producers cannot sell electricity at a higher price than the maximum price, even if there is a willingness to pay for it in the market.

With such a measure, producers lose signals that they should save water, and consumers do not receive signals that they should save energy, when the resource situation dictates it. If the maximum price is set lower than the prices in the countries around us, Norway will be put in an export situation regardless of the national resource situation.

Afry and Menon's assessment is that a maximum price in the wholesale market could result in lower electricity prices for consumers in the short term. The measure will create significant challenges related to the security of supply in Norway over time. In a strained resource situation, the effect on security of supply will be even more challenging.

### *Development of domestic networks and utilization of existing networks*

**Afry and Menon have analyzed the general consequences of increasing capacity between the north and south of Norway. They have looked at two options: increased transmission capacity in Norway from north to south, and increased transmission capacity in the Nordic region.**

**With greater transmission capacity, it is possible to transmit more power to areas with deficits. The opportunities to utilize the flexibility of hydropower will improve, water loss will be reduced and security of supply in the south of Norway will be strengthened. In central and northern Norway, increased transmission capacity will probably contribute to a price increase. The price decline in southern Norway will be more modest.**

## **4 The Energy Act: A historical review**

The Storting's adoption of the Energy Act in 1990 was epoch-making. With this decision, the organization of power supply in Norway was fundamentally changed. The Storting and local authorities were no longer to adopt the power price. There was a distinction between network operations, which was a natural monopoly, and the production and sale of electrical energy, which could be subject to competition. The organization that was introduced in 1990 is still in force.

Then as now, the natural conditions were an important starting point. Norway is a hydropower country, a winter country and an elongated country.

The experiences with the development of the power market and the energy systems after the introduction of the Energy Act must be assessed against the background of the purpose of the Act. What problems was it supposed to help solve, and were the problems solved? To answer this, it is necessary to go back in time and look at how the power supply was organized before the Energy Act. It is necessary to distinguish between the experiences that can be directly linked to market and monopoly regulations, and other decisions that have influenced the development of the power market during the 32 years after the Energy Act was adopted.

### **4.1 Before the Energy Act**

The natural conditions were an important starting point for the organization of the power system. In most places in the country it was possible to find hydropower resources for electricity production. Local authorities and industry themselves found solutions in an early phase of the country's electrification.

Electricity is not a common commodity. It is a fresh product where deliveries must be made instantaneously, it is a self-service market where use varies throughout the day and year, and it requires a separate infrastructure. Good technical and organizational solutions are necessary in all power systems. Norway had an additional challenge compared to the countries that relied on coal power. Coal can be stored and countries can control the supply of energy for electricity production. In Norway, water was the energy resource and the supply varied widely. In the period 1958-2016, the inflow of water was 76 TWh higher in the wettest year than in the driest.

Ensuring power supply throughout the country, throughout the year, in both wet and dry years, was central to the regulation of the sector. The Storting decided that certain power producers - wholesale utilities - should ensure deliveries of electricity for 27 out of 30 years in demarcated areas. This responsibility was called disclosure duty.

The demand for electricity increased, and the Storting was presented with forecasts for the development. The power producers looked to these forecasts and planned power development in their areas accordingly. This model led to a total of more power being produced in the country than was demanded.

The engineers who developed the power system were concerned with managing the water resources and operating the system as efficiently as possible. Power development was expensive, and there was growing opposition to new developments. The conflicts were linked to the natural environment and the relationship with ethnic minorities.

The power plants were built with the capacity to take away more than the normal water flow. Water reservoirs were built so that the producers could retain water in the reservoirs and distribute the production over the day and the year. Eventually, reservoirs were also built that could collect water over several years. Power plants with little or no regulation capability, the river power plants, had to produce when there was water flow and other power producers could hold water back in the reservoirs.

Water was also pumped up to the reservoirs when there was a power surplus.

The first regional joint operation of power plants was already developed in the 1920s, based on agreements between the producers. In 1971, the power producers established a nationwide association, Samkjøringen av kraftverkene i Norge. The carpooling developed a market where producers could sell and buy surplus power. Industry with the option of switching between the use of power and oil or bioenergy also got the opportunity to trade power on the carpooling market.

With the establishment of Samkjøringen, and an exchange for surplus power, the valuation of the water in the reservoirs was put into a system. The carpooling price (price of random power), and expectations about future prices, gave the power producers better opportunities to assess what the water in the reservoirs was worth (the water value). This in turn provided a basis for assessing when they should produce and when they should withhold water. In the spring flood, the price would typically be low, and producers with water reservoirs could hold back water in anticipation of higher prices for the winter.

Co-driving the power plants required transmission lines, and the technical and economic possibilities for building such infrastructure developed over time. For a long time, power projects and industrial establishment were planned together in areas with good water resources. A main network that linked the country together was gradually established, and in 1994 Northern Norway was connected to the network as the last part of the country.

For a long time there were no transmission lines abroad. Right up until 1960, the production of electricity in Norway was equal to the use at all times. This was possible because there was excess capacity, and water that could have provided power production was let past the turbines in wet years. If Norway were linked to a country with coal power or nuclear power, it would be possible to import power in dry years, and have a reserve of power that would otherwise be wasted in wet years. It would be mutually beneficial for both countries. In 1990, when the Energy Act was passed, Norway had transmission connections to Sweden, Finland, Denmark and the Soviet Union. The managers of the largest power companies negotiated the terms for short-term power exchange and established a settlement scheme where the income was distributed. The carpool exchange was central to the organization. The individual producer had no influence on whether electricity was imported or exported.

Water reservoirs, pumping power, a main network that linked the country together, foreign connections and the joint operation of the power plants helped to provide flexibility to handle the large variations in the water inflow. Norway had developed an efficient and solid power system. The system was nevertheless less diversified than in neighboring countries, where energy policy was more integrated with housing and building policy and urban development. They had a large element of district heating in cities and towns. In Norway, electricity was cheaper than in other countries and we became increasingly dependent on electricity for tap water and space heating in the winter season, when the water flow was low. The countries' choice of direction was influenced by the natural conditions for energy production.

#### **4.2 The problem**

There were several indications that the utilization of water resources could be further improved. Although there were good systems for determining water values, the price to the end users was independent of the season and whether there were dry or wet years. At the end of the 1980s, around 5-6 percent of water flowed past ready-to-operate machines when there was a lot of rainfall, because there was no reserve for the power. Few end users were motivated to utilize surplus power or limit electricity use in dry years. Only parts of the industry, and countries we exported to, had access to reasonable power when water values were low.

The price was determined for one year at a time based on self-cost in the various supply areas. The Statkraft price for general supply was set by the Storting and locally the price was set by municipal councils. The price reflected the development costs and how much of the debt had been paid off in the companies. The price for end users varied widely across the country, and within the individual counties. The Storting offset Statkraft's budget because development costs were increasing and there were cost overruns. In 1978, the Storting departed from the principle of using self-cost when determining the state power price and the price was stepped up to over 40 øre/kWh measured in 2021 prices. Power-intensive industry was in a special position with old long-term power contracts with low prices.

As electricity supply had grown through local initiatives, there were a great many distribution works in Norway. There was attention that larger units would be more efficient and there were many associations, often as a result of municipal mergers. In the year before the Energy Act was passed, there were still 235 distribution works, and many of these were very small.

#### **4.3 The Energy Act**

The legal regulations for the energy sector were scattered and in 1990 the legislation was brought together in the "Act on the production, conversion, transmission, sale and distribution of energy etc. (Energy Act)". The purpose of the Act was to "...ensure that the production, transformation, transfer, sale and distribution of energy takes place in a socially rational way,

including that consideration must be given to public and private interests that are affected". After 2002, the purpose has also included the use of energy.

It was the deregulation of the market, with the introduction of market-based power trading, which was the fundamentally new element in the legislation. In the preparatory work for the Odelsting's proposal on the Energy Act, it is stated that "The rigidity in power turnover reduces the value of hydropower and places great demands on storage and exchange with foreign countries" (Ministry of Oil and Energy, 1990). It was in particular the way power was priced that created this rigidity. In order for the utilization of electric power by end users to improve, the price had to be more evenly distributed across the country and between groups. It would provide more equal incentives for energy efficiency. Consumers who had the option of flexible utilization of several energy carriers, such as oil and wood, should be motivated to reduce their electricity use in the event of power shortages. It was also pointed out that it was possible to make the power sector itself more efficient by, among other things, building cheap power plants before the expensive resources were put into use, reducing the number of distribution plants and operating them more efficiently. Market-based power turnover and monopoly control with the grid should help create more flexibility and efficiency in the power sector.

The trend of deregulation was global. Many countries, including Great Britain, Chile and Argentina, were also early adopters of deregulating the power market. These countries chose to privatize both power generation facilities and power lines, partly for ideological reasons. Some countries had a desire to attract foreign capital. In Norway, privatization was not an important part of the debate on deregulation.

There were few legal provisions that laid the foundation for a market-based power transaction. A requirement for a license for the sale of electrical power was introduced. In respect Section 4-3 could be subject to conditions

1. "...the internal organization and accounting in the Norwegian Energy Agency,
2. ...tariffs for transmission and that the concessionaire must make the free capacity and/or transmission capability of the transmission line available to others who are in charge of electricity supply and to producers and users of electrical energy".

It was established that the concessionaire is obliged to "...provide information of a technical and financial nature that is necessary for the exercise of authority...". It was also stipulated that "Without a licence, no one other than the state can carry out the export or import of electrical energy, cf. Section 4-2".

#### **4.4 Ten years of market development**

A number of follow-up points were signaled in the energy law proposal. In the ten years that followed, several changes were made to the organization of the sector, and regulations were established to ensure that the competition would be real and that the network companies would make their operations more efficient.

Statkraft was divided so that Statnett SF was given responsibility for the nationwide transmission grid (the central grid) and Statkraft SF was given responsibility for the state-owned power plants. The companies were organized as state-owned enterprises according to a new law that was established for state-owned enterprises, the State Enterprises Act. This meant that the companies could keep the same type of accounts as limited companies, with depreciation of assets. Opening balance sheets were set for the companies, and they got a better overview of the values. They were given greater freedom in the financing of the

business. From 1993, all companies in the power supply had to keep accounts according to the principles of the Companies Act, regardless of company form.

It was an important recognition in the preparations for the Energy Act that the electricity in the grid was not affected by power contracts entered into between sellers and buyers. It was physical laws that governed the flow. When someone switched power suppliers, the physical reality would be unchanged. It was therefore not rational to base transmission tariffs on geographical distance. A point tariff system was introduced where producers paid one tariff to supply power to the grid, while end users paid one tariff to take power out. The introduction of the point tariff system was an important regulation which ensured that customers could easily access the grid and switch power suppliers. NVE was given the task of carrying out monopoly control with the grid.

In the regulations, it was stipulated that customers should have access to the network on non-discriminatory terms. On the end-user's electricity bill, the net rent and the electricity price were displayed separately.

Frameworks were set for the design of network tariffs and for the network companies' income. In the first years, the network companies' returns were regulated. Later, a model was developed to compare the efficiency of the companies, and from 1997, less efficient companies have had a lower return than the most efficient. In the regulation, account is taken of the network companies' tasks and various framework conditions, including geographical and topographical differences. Eventually, a scheme was introduced whereby consumers received compensation in the event of longer interruptions in the supply of electricity.

A market place for power was established so that pricing was transparent. The carpooling provided a good starting point for creating such a marketplace. Statnett Marked, later Nord Pool, was established in 1993 as a subsidiary of Statnett. A spot market was established where the price was formed for each hour. There were also markets to balance the system within the hour and for longer standardized contracts. These markets were open to manufacturers, power suppliers and major end users.

Regulations were laid down for the measurement and settlement of power. For household customers, it was not rational to measure electricity use hour by hour, or trade directly in the spot market. Own electricity suppliers found a market in serving small customers. In the absence of hourly metering, arrangements were made so that household customers could be billed according to a consumption profile that applied to all customers in larger areas. From 1997, household customers could change electricity supplier free of charge.

The organization of foreign trade was not significantly changed in the first years after the Energy Act, the short-term power exchange was continued through the Statnett market. The settlement scheme for the trade was eventually discontinued.

In the power market, the market design itself and the regulatory framework have been important to ensure well-functioning competition. The main structure of the regulations that were introduced under the Energy Act has remained, although it has been adjusted and tightened several times. NVE has been the regulator for the market. The Norwegian Competition Authority has supervised acquisitions and mergers between power suppliers. The Norwegian Consumer Protection Authority has carried out inspections in accordance with the Marketing Act, the Price Information Regulations and the Right of Cancellation Act.

#### **4.5 Experiences**

It has been 32 years since the Energy Act was passed. An assessment of the experiences with the Energy Act must be made on the basis of the problems it was intended to help solve. Did

the market price reach the end users, and was there a consumer response to the price? Was the price equalized between customer groups? Was it effective competition? Did we get a more efficient power grid and fewer companies? Did the power sector as such become more efficient? The market development has been followed closely by the authorities, research environments, analysis environments, the industry itself, end-user groups and stakeholders who supply products and services.

Figure 4.1 shows the development in the price of random power from 1980 to 1990 and the spot price in Oslo from 1991 to 2021, converted to fixed 2021 prices. The price has varied around 33 øre/kWh on average both in the spot market and in the market for random power. There have been periods of low rainfall and high prices, and other periods of high rainfall and low prices. The figure also shows the state power price from 1980 to 1990, which was gradually adjusted up to a level that should reflect the cost of building new plants. The Statkraft price was thus independent of the variations in water inflow. In 1990, the state power price was 41 øre/kWh, while the resource situation this year, represented by the price of random power, should dictate a price of approx. 17 øre/kWh. In other years, the price of random power was higher than the price of state power, which indicates that there was little rainfall.

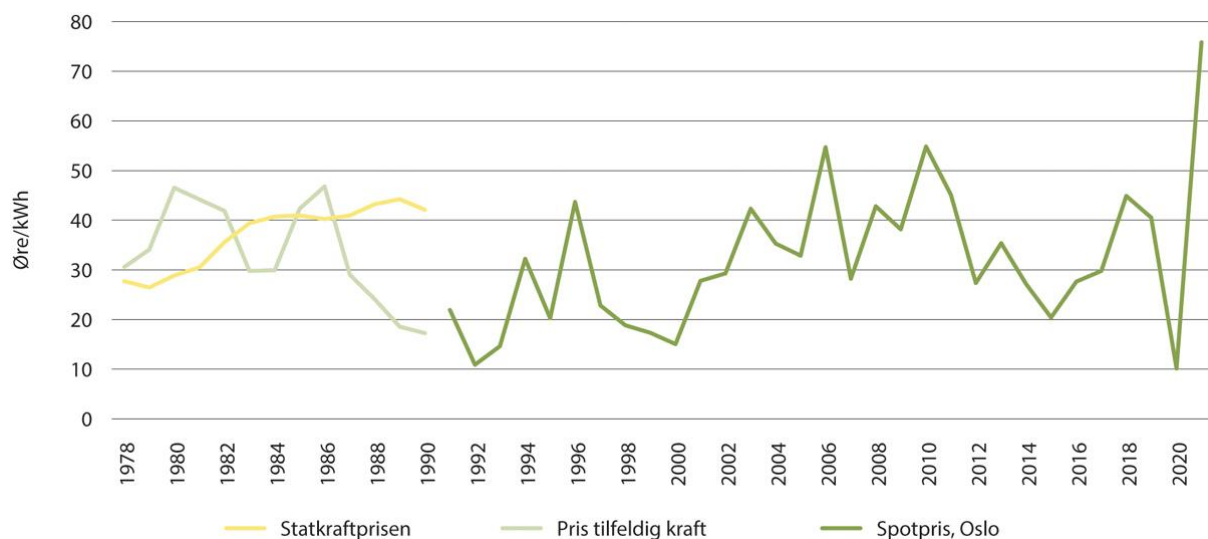


Figure 4.1 Price of random power, state power price and spot price, fixed 2021 prices. Ore/kWh

Statistics Norway and the Ministry of Petroleum and Energy.

The power year 2021/2022, with unusually high spot prices in southern Norway, differs greatly from the experiences from the first 30 years of the Energy Act, and this is discussed separately in chapters 3, 11 and 13.

#### 4.5.1 Market access

The Energy Act stipulated that all end users should have market access and the opportunity to benefit from the low prices seen in the market for random power, and be faced with higher prices when resources were scarce. For long periods, the spot price has moved down towards the level of the fixed price agreements for power-intensive industry and wood processing. It was expected that end users would reduce their electricity use when the price was high. If this was to be possible, it was important that all customers had market access.

Market access for end users was gradually improved and you could eventually change supplier free of charge simply by contacting a new supplier. While before the Energy Act large variations in price were seen within the individual county and across the country, it was now up to the end users themselves to obtain good conditions. An increasing proportion of end users in general supply have chosen to change supplier and link the price to the spot price.

Electricity is a homogeneous product, there are a large number of power suppliers and the Consumer Council has kept an overview of the suppliers' conditions. Even if it is arranged for market access, dealing with the product electricity can be complicated, especially for household customers. It happens that power suppliers change conditions without consumers realizing this. There are cases where power suppliers take a very high advance, although this is not the general rule. At the same time, some power suppliers are developing additional products, such as apps where end users can monitor electricity use and prices. Aggregators are about to enter the market that can sell flexibility from a group of customers to network companies with limited capacity. Energy efficiency and flexible heating solutions are increasingly mentioned in connection with alternatives to network investments and opportunities to balance the power system.

The work to facilitate a more well-functioning and consumer-friendly electricity market is still ongoing. In the autumn of 2022, changes were adopted in the price information regulations and the regulations on power sales and network services with stricter requirements for information during marketing and on the invoice.

#### **4.5.2 Response to prices**

When the first dry year (1996) brought price increases in the spot market, the market was still immature. Households and industry mostly had fixed prices and the price signals reached the end users to a small extent. When the autumn of 2002 came with little rainfall and high electricity prices, there was a market response beyond the winter, both among households and business customers. Power-intensive industry and wood processing with long-term contracts chose to some extent to resell the power when prices became high. The wood processing industry also took advantage of the opportunity to use bioenergy and oil instead of electricity. There were also dry years with high prices in 2006 and 2010. In a report from 2012, Statistics Norway concludes that "In all the analyzes we have done, we see that there is a price response to demand, both in the short term in the spot market and in the slightly longer term in the retail market" (Halvorsen, 2012). In such years with high prices, we have also seen that the sale of oil products and the use of firewood have increased, sales of heat pumps have picked up and district heating plants have reduced the proportion of electricity in the fuel mix.

#### **4.5.3 Competition**

In order for the intentions of the Energy Act to be fulfilled, it was important that real competition be established in the market. In the first years after the Energy Act, when the spot price became very low, the Directorate of Prices suspected that the electricity producers were trying to collaborate to raise the price, but this did not lead to sanctions against the companies. After a joint Norwegian-Swedish power exchange came into place in 1996, and several countries gradually joined the market, the individual producer has gained a less strong position and the danger of harmful exploitation of market power has been reduced. Investigations carried out by the Norwegian Competition Authority in 2017 and 2021 indicate that companies are largely trying to avoid breaking the competition rules.

#### **4.5.4 Efficiency in the power sector**



No special investigations have been carried out into the efficiency of investment and operation of power plants and grid operations in accordance with the Energy Act.

Flexibility on the consumption side should contribute to more water being used at high water flows because it could be set aside for the power in the market. Less water should flow past ready-to-use machines. Flexibility on the consumption side makes an important contribution to utilizing more of the power when it is cheap. At the same time, the possibility to alternate between the use of oil and electricity has gradually decreased in Norway, and from 2020 it was forbidden to use oil for heating in buildings. New sources of flexibility are now being developed with batteries, hydrogen, heat storage etc. Increased exchange capacity has also largely contributed to the provision of power in wet years.

Mergers of online companies have continued. In 2022, there will be less than 100 grid companies in Norway, compared to 235 distribution works in 1989. The studies that have been carried out show an improvement in productivity in the companies of between 0.3 and 1.3 per cent per year on average (RME, 2022).

More than 90 companies engaged in sales of power in 2020, against approx. 30 in 1997. This is a marked increase which must partly be attributed to the fact that there has been a requirement for a company-wide separation between the grid and business exposed to competition, and partly to the arrival of new independent electricity suppliers. More than 40 companies operated only retail sales in 2020, the others were either pure wholesale works (approx. ten units) or operated both in the wholesale market and the retail market.

Security of supply in the power system has been good in Norway. It has been an important question whether the deregulated market would provide sufficient signals for new investments. In the first years after the Energy Act came into place, prices were very low. At the same time, there was also good production capacity in the system, so in this sense there was no need for high prices that would provide incentives for more development. Investments picked up beyond the 2000s, both in networks and production. Investments in production capacity picked up in particular after the electricity certificate market, which was a subsidy scheme, was introduced. The investments came mainly in the form of wind and small power.

#### **4.6 Other decisions have affected the power system**

The Energy Act provided a framework for deregulation of the power sector. Deregulation did not mean that we got a power sector with less regulation, on the contrary, the new market organization required that a number of new regulations be introduced. The market, and the investment and operation of facilities, is more thoroughly regulated than was the case before 1990. In addition, a number of other decisions have also been taken which also affect the power system without being directly linked to the introduction of market-based power trading.

The grid is not exposed to competition in the same way as power sales and must be planned by the grid companies, as was also done before the Energy Act. Planning is coordinated through regional power system investigations in which the various network companies are required to participate. The municipalities are also involved in power system planning. It has been challenging to get a real assessment of various measures against each other. For example, district heating and other alternative solutions are not included to a small extent when assessing the need for network reinforcements. Statnett is responsible for planning and developing the transmission network. NVE grants licenses for the construction of lines and it is often a time-consuming process. The Strømnettutvalget has given a number of recommendations to shorten the processing time for grid installations, and to make better use of existing capacity (Strømnettutvalget, 2022).

Scarcity of transmission capacity meant that Statnett introduced price ranges in the network. With price ranges, different prices were formed on the various sides of the bottlenecks in the network so that there was a balance between production and consumption. Price ranges highlight the limitations of network capacity. Sweden used counter-purchases for a long time to deal with bottlenecks in the transfer between different areas. Svenska Kraftnät then paid producers to increase production behind bottlenecks so that the price fell. The expenses were distributed among the online customers. Under pressure from Denmark, which complained that Sweden was restricting its imports, Sweden introduced four price ranges to deal with internal bottlenecks. Denmark, for its part, has introduced two price zones. Most countries in Europe still only have one price range and still exclusively use counter-purchases in their bottleneck management.

There have generally been small differences in the price between the price areas, with the exception of a period around 2008 when the price was higher in the northern parts of the country than in the southern. With the establishment of new transmission lines, the bottleneck was resolved. Development of transmission lines requires a licence, and the proceedings take many years. In 2021/2022, the network capacity between north and south has been fully utilized for a large part of the time. The price differences between the areas have been unusually large, with very low prices in northern parts of the country, see chapter 11.

Development of power plants requires a licence. There is currently good profitability in both hydropower and wind power, but there is often great opposition to the development projects and the license processing time is long. Gas power plants, which could provide some flexibility in the system, there has been great resistance to building in Norway due to greenhouse gas emissions. The gas power plants that have been built have been shut down or are in the process of being shut down. Reference is made to chapter 10 for discussion of production possibilities.

With the Energy Act, new production should initially come if it was profitable. Politically, there were nevertheless strong wishes to stimulate power development. From 2012 to 2021, new production facilities were subsidized through a joint Norwegian-Swedish electricity certificate system. The reason for the scheme was that Norway should achieve the target of a renewables share of 67.5 per cent in 2020. The target was set after discussions with the EU to include the renewables directive in the EEA agreement (Ministry of Foreign Affairs, 2011). New hydropower plants and wind power plants have dominated the electricity certificate scheme. Consumers within general supply have been obliged to buy certificates, and in that way covered the costs of the scheme. The electricity certificate price has been low in recent years as a result of wind power becoming profitable without certificates. Plants with a total normal annual production of 20.7 TWh, established after January 2012, were covered by the electricity certificate scheme on the Norwegian side when it was closed to new plants at New Year 2022.

It was decided to establish several foreign connections, most recently to Germany and the United Kingdom. The framework for granting a license to foreign connections follows from the Energy Act. A license for new foreign connections outside the Nordic region is given by the Ministry of Petroleum and Energy. Other licenses are granted by NVE. Increased flexibility in the power system, related to countries with thermal power generation, has been part of the argument for establishing foreign connections. Imports for dry years and exports in wet years have been important for long-term security of supply. With the exchange of power throughout the day, we have utilized the hydropower's particularly good ability to regulate production quickly up and down, thus better utilized the water reservoirs. At the same time, this has contributed to the influence of the price in Norway being influenced by

the price in the countries we trade with. There has also been attention to the environmental consequences for more power driving of the power plants.

The fact that a large proportion of the heating requirement is covered by electric power characterizes the consumption profile for power over the year in Norway, and provides a high power output during cold days in winter. The power margin has decreased in the last eight - ten years (NVE, 2022). Rapid electrification of the transport sector and industry, new industrial activity and the development of power -intensive devices may explain some of the development. Changes to more renewable energy in neighboring countries have also made effect more valuable. The network companies are aware that the network is fully utilized just a few hours a year when it is cold and that there is otherwise available capacity. An element of power pricing of the grid has been introduced. There is great R&D activity to create new forms of flexibility that can meet this development.

In 2000, Enova SF was established to stimulate wind power development, energy efficiency, and to limit the use of electricity for heating. Enova received a fund financing and great freedom to work long -term with the development of instruments and projects. The specific goals were to contribute to the prevalence of water -borne heat based on renewable energy sources (4 TWh in 2010), wind power that was still an immature technology (3 TWh in 2010) and energy efficiency. Enova was established to support a "... energy policy that supports an ambitious environmental policy" (Ministry of Petroleum and Energy, 1999). The work should "... prepare us at a future where energy, and especially electricity will be a scarce and more valuable good". There have also been strict energy requirements for construction and products, see a more detailed review of energy consumption and energy efficiency in Chapter 10.

Enova has contributed to energy efficiency, especially the development of new technologies and markets for energy efficiency measures. They have also contributed to some district heating, but our dependence on electric heating has increased. There has been some requirement for flexible heating in larger buildings, but electric heating is nevertheless used to a large extent.

Norway has undertaken ambitious climate obligations. Electrification of transport and industry, and a ban on using oil and kerosene for heating, are important part of the efforts to reach climate obligations. Norway is in a transitional phase where new requirements for rapid restructuring are also set in the power system. Enova has become a climate tool, a driving force and facilitates the restructuring. They also support, among other things, wind power by sea and hydrogen to develop new technologies and markets.

A number of taxes and fees are charged to power producers and end users. The electricity tax has been lower in Norway than in most other countries, and the industry, which is covered by the EU's exception, has exemption. In a renewable power system, the basic interest rate can occur and it has provided a good basis for taxation. When the power price is set in the market and everyone pays the same price, all manufacturers will receive the same income per kWh regardless of what costs they have had in investment and operation. Access to local resources on which there is scarcity can give rise to returns beyond what one can expect from other investments. This profit is often called basic interest rate. The size of the basic interest rate will vary between projects with different cost levels and between periods of different power prices. In the power sector there are large cost differences, with different production technologies and resources for the various facilities. In Norway, hydropower plants are taxed through several taxes, including the basic interest tax, so that a large part of the values accrue to the community. The state's total revenues from the basic interest tax have been increasing since it was introduced in 1997, but varies with the power price. In 2018, which was a year of

high prices, revenues were NOK 10.7 billion, while in 2020 when the price was low, the state's income from the basic interest tax was NOK 2.3 billion.

#### 4.7 Today's standpoint

The power sector has been, is and will be very fundamental to reaching a number of social goals. On this basis, the purpose of the Energy Act is still relevant. Production, transformation, transfer, turnover, distribution and use of energy shall take place in a socially rational way, including the public and private interests affected.

One important reason why the Energy Act was designed with a market -based solution for power sales were the physical conditions for power generation in Norway. Energy access varied significantly between years and over the year. We are still hydropower dominated, with an increasing element of wind power. Both technologies depend on the weather conditions, see Chapter 8. The market provides a good basis for utilizing available water and wind resources and coordinating the water disposal in 1739 hydropower plants (as of 1.1.2022) with different characteristics and resource situation.

The power sector is infrastructure that will now be further developed to achieve society's goals for the green shift. It is new that the power sector has become crucial for a green restructuring and that the restructuring must take place so quickly. In order to achieve the climate obligations, it is required that fossil energy be replaced by electricity both offshore, in the existing industry and in the transport sector. In that transition, green industrial production with high power requirements will also provide new jobs.

**Norway is today more integrated with the European power system, with an exchange capacity of 9 GW, which represents about 1 TWh per week, see Chapter 11. We are more influenced by the power and resource situation in the Nordic countries and the rest of Europe. The prices formed in the market reflect the underlying resource and market situation. It gives signals that it must be invested, and it also gives signals of energy saving and flexibility.**

**At the same time, Europe replaces thermal power plants (nuclear power, coal power and gas power) with power generation based on renewable energy sources that are little adjustable. Thus, the countries we interact with increasing challenges in balancing the system. The power price will be very low in periods of a lot of wind and sun, and very high in other periods. This is a significant change in the European power system, which is increasingly important to Norway. The challenges of adjusting the power systems are great for all countries. No country has a completed plan and regulatory and market solutions on what the system should look like in 2050, when it is emission -free.**

With the significant, structural changes that occur in the energy markets, the development of the energy balance, the balance of power and prices is more uncertain than in previous years. From today's point of view, however, it is expected that power use will increase in the years to come, and that the grid capacity will be scarce. Some elements appear important for the power sector to help realize important societal goals, and at the same time retain competitive prices for business and sustainable household prices. Keeping a good security of supply is a premise for the road choices to be taken, see Chapter 12.

Some key elements in the development of the future energy system are:

**Energy efficiency, new heating solutions and flexible consumption:** The power market is still a self -sufficiency market. However, new technologies make it possible to control consumption in a completely different way than in 1990. Management of consumption can contribute to the balance of power, better utilization of grid capacity and reduced power

consumption. It is possible to streamline energy consumption in all sectors, and utilize energy that today goes to play in the industry. Here are great potentials that can be extracted. See mention in Chapter 9.

**Power development:** There are many alternatives for power development, including wind on land and at sea, solar power and increased hydropower. In particular, adjustable power generation will be valuable. See discussion in Chapter 10.

**Network development:** Utilizing the grid capacity well and building more capacity. Bottlenecks in the network can be built down. The Energy Commission refers to NOU 2022: 6, net in time, for discussing the development of the power grid.

**Collaboration with Europe:** Decisions made through EU cooperation and in individual countries can influence how our energy resources are valued, whether the resources are effectively utilized and in some cases end-user prices. It is important to participate in the forums where the framework for the market is decided. Our strategies must be adapted to actual development. See discussion in Chapter 13.

## **5 Energy consumption and production in Norway today**

The abundant access to water resources in Norway has characterized the development of the energy system, our business structure and how we heat our buildings. The location of the water resources has been crucial to where the power plants were built, and together with the settlement pattern have determined what the transfer network for power looks like today.

Hydropower, the large element of power-intensive industry and widespread electric heating of buildings are special features that distinguish the Norwegian energy system most from other countries. At the same time, there are several energy sources and energy carriers that complement the image of the hydropower country and play an important role in the system. The various consumption groups in Norway have their own characteristics and opportunities to utilize different energy resources.

### **5.1 The energy consumption**

The total energy consumption in Norway, including the shelf, was 326 TWh in 2021 (Statistics Norway, 2022). This was distributed with 138 TWh of electricity, 165 TWh of fossil, 16 TWh bioenergy and around 7 TWh district heating (which is significantly fired with bioenergy).

There has been significant growth in energy consumption from 1990 to 2000, and a slightly lower growth from 2000 to 2021, as shown in Figure 5.1. Most of the growth in the last period came from oil and gas extraction, chemical industry and aluminum. In addition, there was growth in the transport sector, especially road transport. The service sector also had clear growth, while there was a weaker household growth.

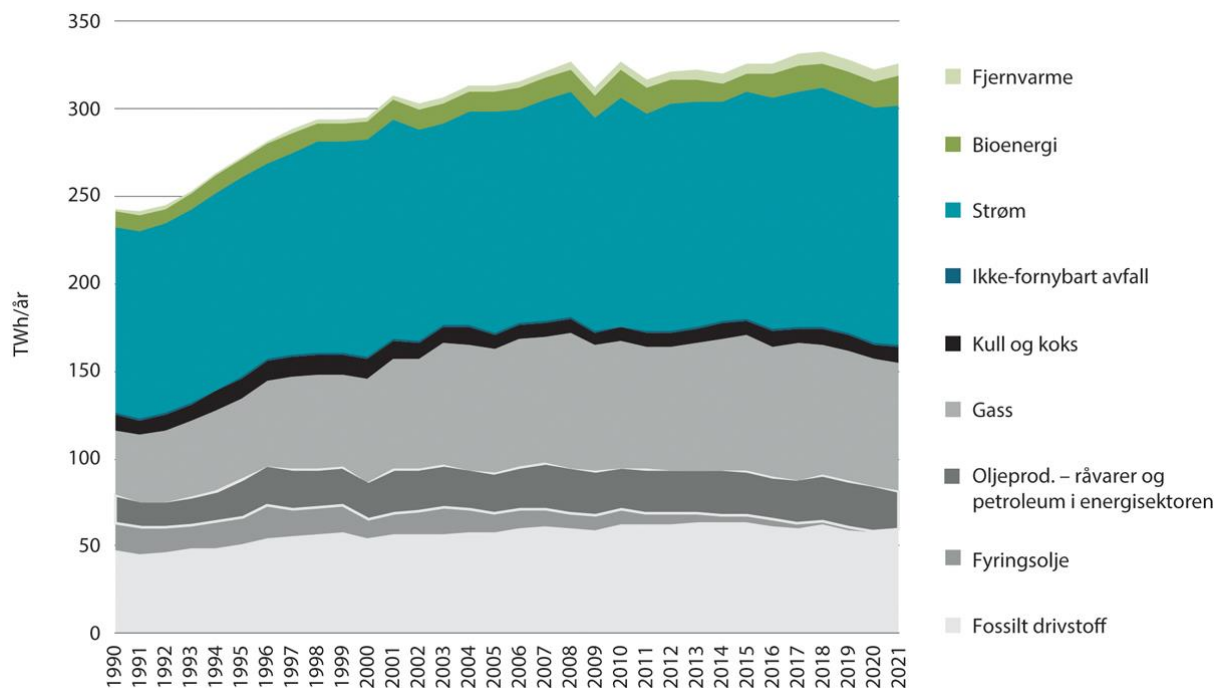


Figure 5.1 Development in total energy consumption in Norway, 1990-2021, TWh/year Statistics Norway (2022).

Norway has a high and increasing proportion of electricity in energy consumption compared to other countries. The use of district heating and bioenergy is also increasing, while the use of fossil energy products is reduced. In addition to the energy consumption that appears in the statistics, approx. 10 TWh Environmental heat via heat pumps.

The different sectors differ from each other in how they use energy and what they use it for. Figure 5.2 shows energy consumption in 2021 distributed among sectors and energy products. Most of the electricity is used in the industry (40 per cent) and in buildings (50 per cent). The transport sector, industry and energy sector use some fossil energy. Energy products used as raw materials in production processes are included in the energy use figures for the industry. The energy consumption in oil and gas plants on land and at sea, and electricity for petroleum systems are included in the figures for the energy sector.

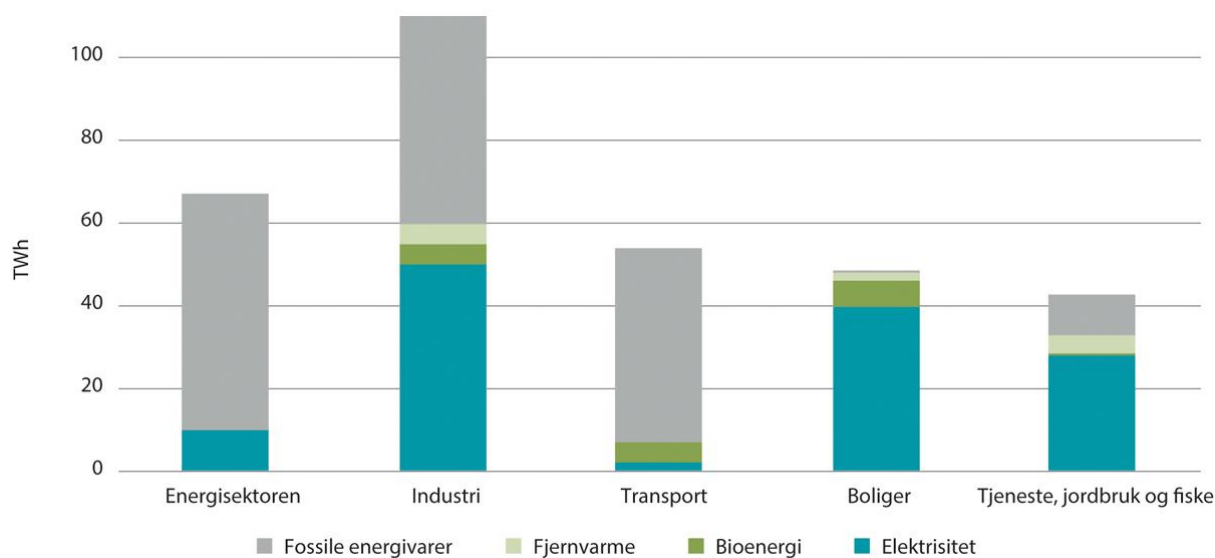


Figure 5.2 Total energy consumption in Norway 2021, per sector and energy, TWh Statistics Norway.

### 5.1.1 Energy use

Buildings in Norway are often divided into two groups, service sector and housing. The service sector includes many different types of vocational buildings. Housing includes everything from detached houses to block apartments. Energy use in housing is often referred to as household energy consumption.

The energy consumption in housing in Norway is 47-48 TWh per year, and two-thirds go to heating rooms. About 12 per cent of the energy consumption in homes goes to tap water and a little more than 20 per cent goes to electricity-specific equipment. By electrical-specific consumption that can only be covered by electricity, such as lighting, TV, PC, washing machine and refrigerator. Electricity for heating amounts to 22-24 TWh, then follows bioenergy with 5-6 TWh, and district heating with 1-2 TWh.

The annual energy consumption in the service sector is just over 40 TWh, of which around 28 TWh is electricity. The service sector also includes agriculture and fishing. About half of the energy consumption in this sector goes to electric specific purposes, such as lighting, fans, pumps and appliances. A small proportion goes to heating tap water, while just over 40 per cent go to room heating. Cooling is a fairly small proportion. The heating in the service sector is covered by approx. 8-9 TWh of electricity, 5 TWh district heating and some bioenergy. Fossil energy products are largely phased out of the building sector. As shown in Chapter 4, a large proportion of heating in Norway is based on electricity. This means that the use of electricity is affected by the weather. This connection between outside temperature and power use is stronger in Norway than in other countries.

Figure 5.3 shows the distribution of power use over the year as a percentage per week in different areas in Norway.

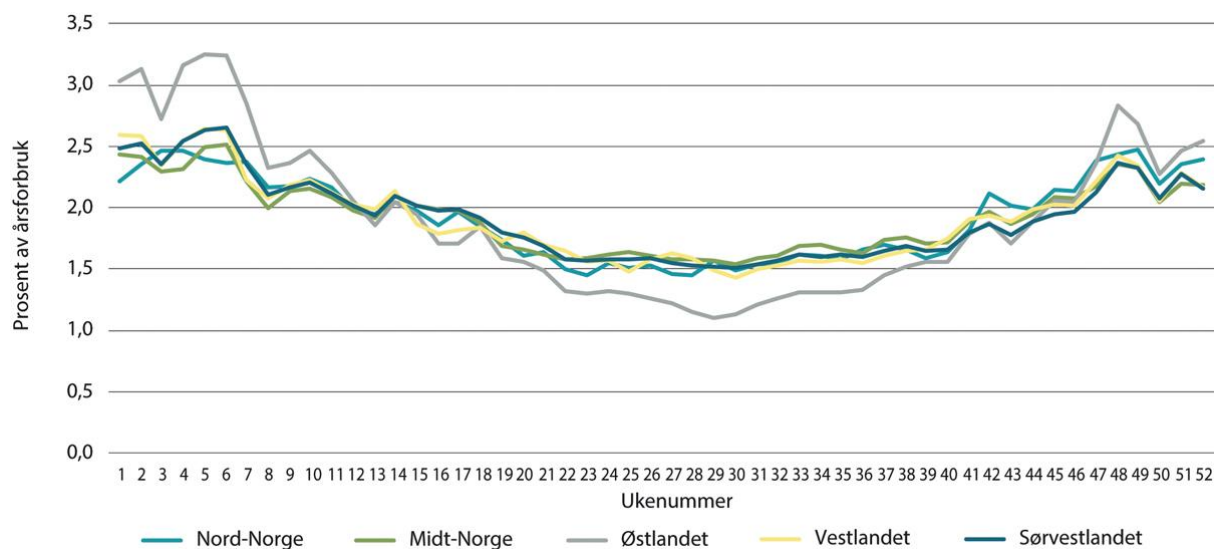


Figure 5.3 Percentage of weekly distribution of power use in 2021, for the five price areas Nordpool.

While energy consumption in buildings is largely affected by the outside temperature, energy consumption in the industry is less affected. Therefore, in price areas with a lot of industry, the total use of power will vary less than in price areas where energy consumption in

buildings is a larger proportion. The use of power in Eastern Norway, which has less industry than elsewhere in the country, is therefore particularly high in winter and low in summer.

The total use of energy in housing has increased relatively little in the period 2000 to 2021, although population growth has been 20 per cent in the same period. This can be explained, among other things, by the fact that energy consumption in buildings has become more efficient. Household appliances and some technical solutions in commercial buildings have also become more efficient. In addition, many heat pumps have been installed.

### 5.1.2 Heat pumps

Heat pumps utilize ambient heat, so the amount of heat energy supplied from the heat pump is larger than the amount of electricity used in the heat pump. Calculations show that in 2015 heat pumps contributed around 8 TWh of surrounding heat (NVE, 2016). This has now increased to over 10 TWh. Heat pumps reduce the need for other energy supply, such as electricity, district heating or bioenergy.

The heat pump sale is dominated by heat pumps that use ambient air as an energy source (air/air heat pumps). Figure 5.4 shows that in 2021 there was a strong increase in sales. The spot price for Oslo is shown on the right axis, and the sale of heat pumps appears to be related to the power price. Heat pumps are an important technology in Norway, and can have an even greater distribution in the future.

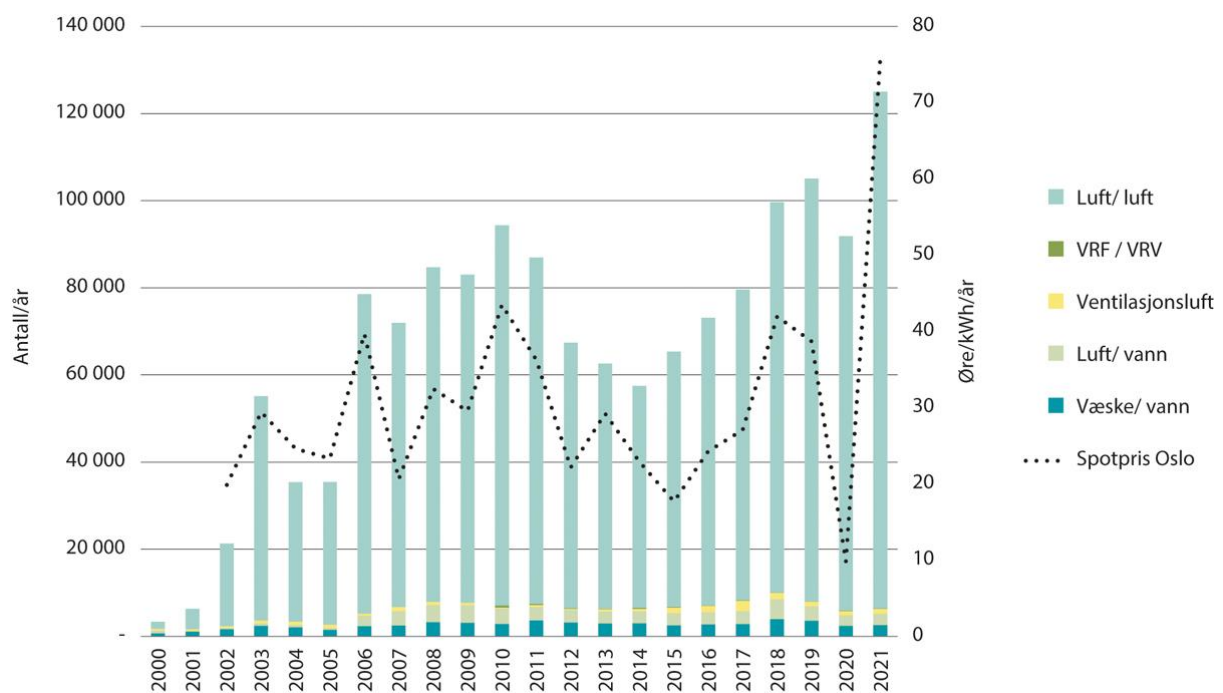


Figure 5.4 Sales of heat pumps in Norway (left axis) and spot price Oslo (right axis). 2000-2021

Novap and Nordpool.

Over 1.1 million heat pumps have been installed in Norway, and Norway has Europe's highest proportion of heat pumps in households (NVE / Novap, 2022) (Rosenow & Gibb, 2022) (IEA Heat Pumping Technologies Program, 2022). Liquid-water or air-water heat pumps assume that the building has water-borne heat, and it has limited distribution in Norway.

### 5.1.3 Energy use in the industry



Energy use in the land-based industry is around 112 TWh per year, including energy products used as raw material for energy purposes. About 49 TWh of the industry's energy consumption is electricity, while 4 TWh is bioenergy and 0.6 TWh is district heating.

A lot of fossil energy is still used in the industrial sector, around 52 TWh. This is distributed like this:

- Natural gas - 27 TWh
- charcoal and coke - 8 TWh
- Oil and fossil fuel-15-16 TWh
- Non-renewable waste-1 TWh
- heating oil - 0.7 TWh.

Good access to power, and at competitive prices, has contributed to the development of a lot of power-intensive industry in Norway. The industrial sector is characterized by many large individual players with high energy consumption. The largest single groups are the metal industry, chemical industry and wood processing. The energy consumption is to meet cooling and heating requirements, in processes and for the operation of electrical equipment.

There are no statistics showing the distribution of energy consumption for various purposes in the industry, but it is estimated that land-based industry uses around 19 TWh of energy for heat and cooling purposes (Oslo Economics / Asplan Viak, 2020). For example, the wood processing industry used around 5 TWh for process heat in 2018.

Figure 5.5 shows how the use of energy products is distributed among, and within, the large industrial groups. Energy use in the oil and gas industry (incl. Refiner) is not included.

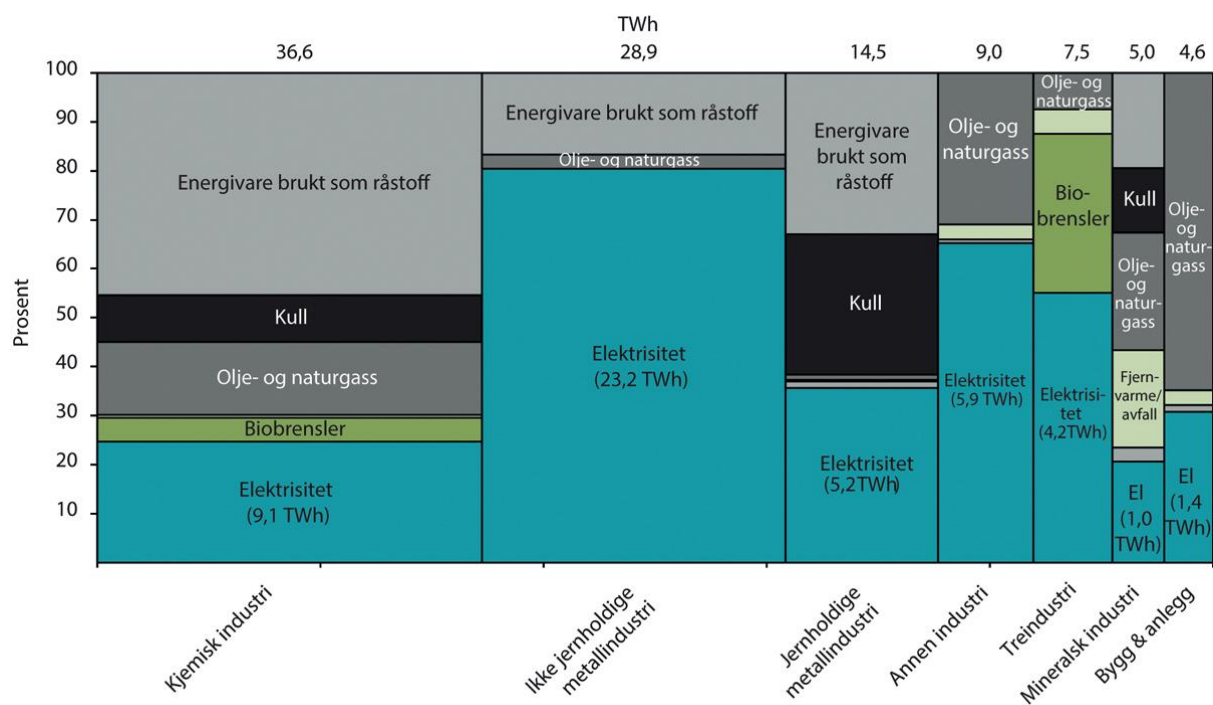


Figure 5.5 Energy use in land-based industry distributed among industries and energy carriers, 2021. TWh/year and percentage

Oslo Economics/SINTEF, based on Statistics Norway (2022).

According to Statistics Norway, the 40 largest facilities in Norwegian industry account for more than 80 per cent of energy consumption and 80 per cent of the power use in the industry. The same facilities also account for 90 per cent of greenhouse gas emissions in Norwegian industry. We find these 40 largest plants in the industries metal industry, chemical industry, mineral industry, wood processing and oil refineries. In addition, there are four large onshore facilities associated with the petroleum sector in Norway, which together use several TWh of Strøm and release millions of tonnes of CO<sub>2</sub> (Statistics Norway, 2022).

### 5.1.4 The energy sector

The energy sector, including the oil and gas industry with refineries, accounts for about 67 TWh, which is distributed to 10 TWh of electricity, 53 TWh gas and 4 TWh of petroleum products. Most of the electricity in the energy sector goes to oil and gas installations on the Norwegian continental shelf and gas plant on land, but a small proportion also go to operate the power stations in the land-based hydropower system. Some electricity is also used in the district heating systems. The petroleum products in the energy sector are used, among other things, as fuel in offshore boats and in diesel generators on the platforms.

### 5.1.5 Transport

The annual energy consumption in the transport sector is 53-58 TWh, and around 90 percent of this is fossil. Figure 5.6 shows the development in energy consumption from 1990 to 2021.

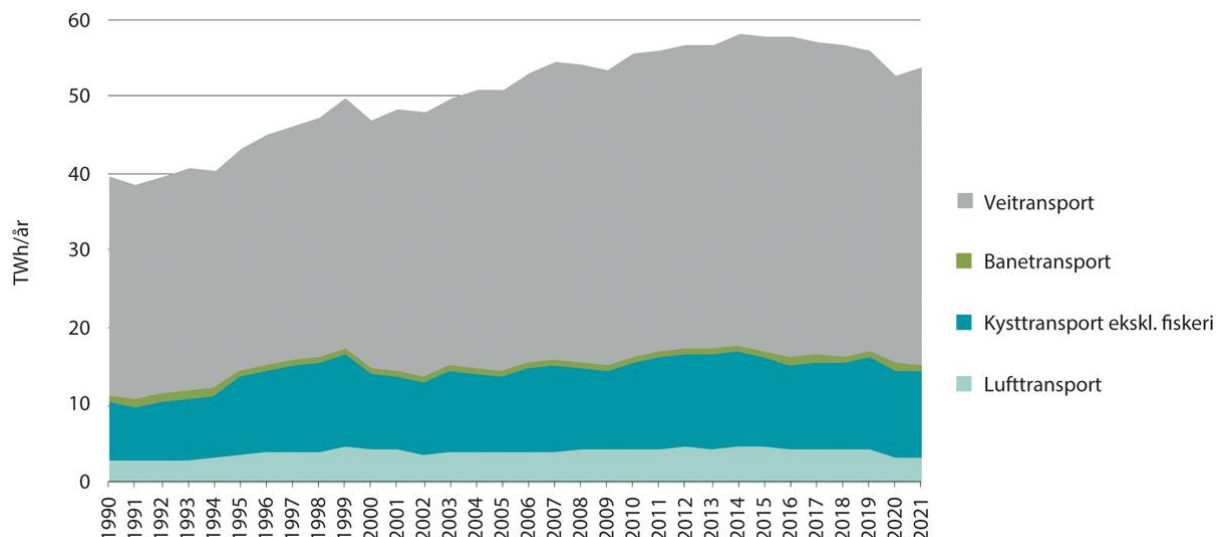


Figure 5.6 The development in energy consumption for transport, distributed in mode of transport. 1990-2021. TWH/Year

Statistics Norway.

Road transport accounts for around 70 per cent of the energy consumption in the transport sector, followed by coastal transport of just over 20 per cent and air transport of approx. 7 percent. The energy consumption in road transport has grown the most since 1990, from 28-29 TWh to under 40 TWh today. Coastal transport has experienced weak growth over the last 20 years, while energy consumption in air transport has been relatively stable, with the exception of 2021, when the pandemic hindered travel activities.

There has been a transition from diesel and gasoline to electric cars in road transport. This has contributed to a decrease in the total energy consumption in the transport sector, because battery -electric engines are about three times as effective as combustion engines. In 2021, electric vehicles accounted for 64.5 per cent of the sale of passenger cars and 17 per cent of

sales are vans. Electric cars' share of new car sales has continued to increase in 2022 (Norwegian Electric Car Association, 2022).

In 2021, there were 500,000 electric passenger cars in Norway, and they constituted almost one fifth of the total passenger car park in the country. Larger road transport vehicles sold today are run by fossil energy sources. In track transport, however, mostly are electric. Figure 5.7 shows the composition of energy consumption for transport.

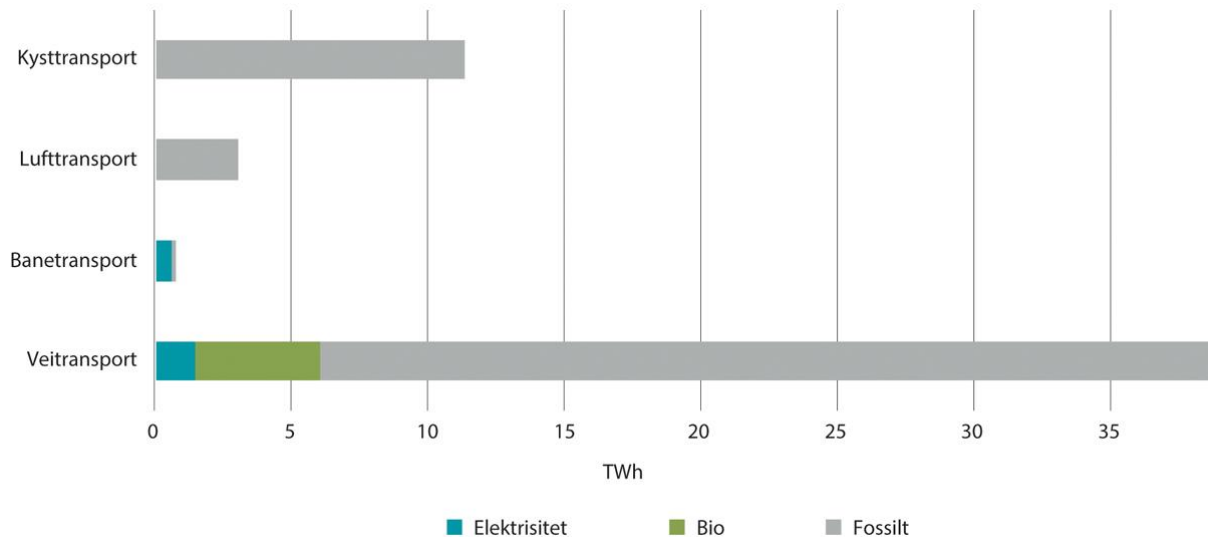


Figure 5.7 Energy use in the transport sector distributed by energy, 2021. TWh Statistics Norway.

The transition to more use of electricity in road transport is expected to continue. Favorable framework conditions for electric vehicles, ever better charging options and more electric car models are strong driving forces behind the development.

Also in coastal transport and fishing there is electrification. New ferries are ordered with electric propulsion, there are examples of electric speedboats, hybrid solutions are installed in older boats, etc. Charging infrastructure is established in ports. Hydrogen and ammonia also appear as important energy carriers in shipping traffic in the future. For larger ships in long - range, the trend towards zero emissions is slow, but hydrogen and ammonia can become important energy carriers to phase out fossil fuels.

At construction sites, electrical construction equipment is used, and both electricity and district heating are relevant for building drying. Some of the electrification solutions are still in an early stage where technologies are tested and demonstrated. The machines are manufactured on a small scale, or vehicles, vessels and construction equipment are rebuilt from fossil operations.

## 5.2 Power production

Norwegian power generation is mainly renewable. The proportion of renewable power generation will vary with energy prices and the weather, but is around 98 per cent in a normal year. Very few countries in the world have a higher renewable share in power generation.

Hydropower accounts for 88 per cent of power generation in a normal year, while wind power represents ten per cent. The rest consists of some solar power and thermal power generation based on fossil fuels, mainly gas power on Mongstad and Melkøya. Norwegian power generation is also characterized by the fact that it is largely flexible, due to the large proportion of adjustable hydropower.

### 5.2.1 The Norwegian power plant fleet

There were 1832 power plants in Norway at the beginning of 2022. These power plants had an expected production of 156.9 TWh this year with normal weather. (NVE, 2022).

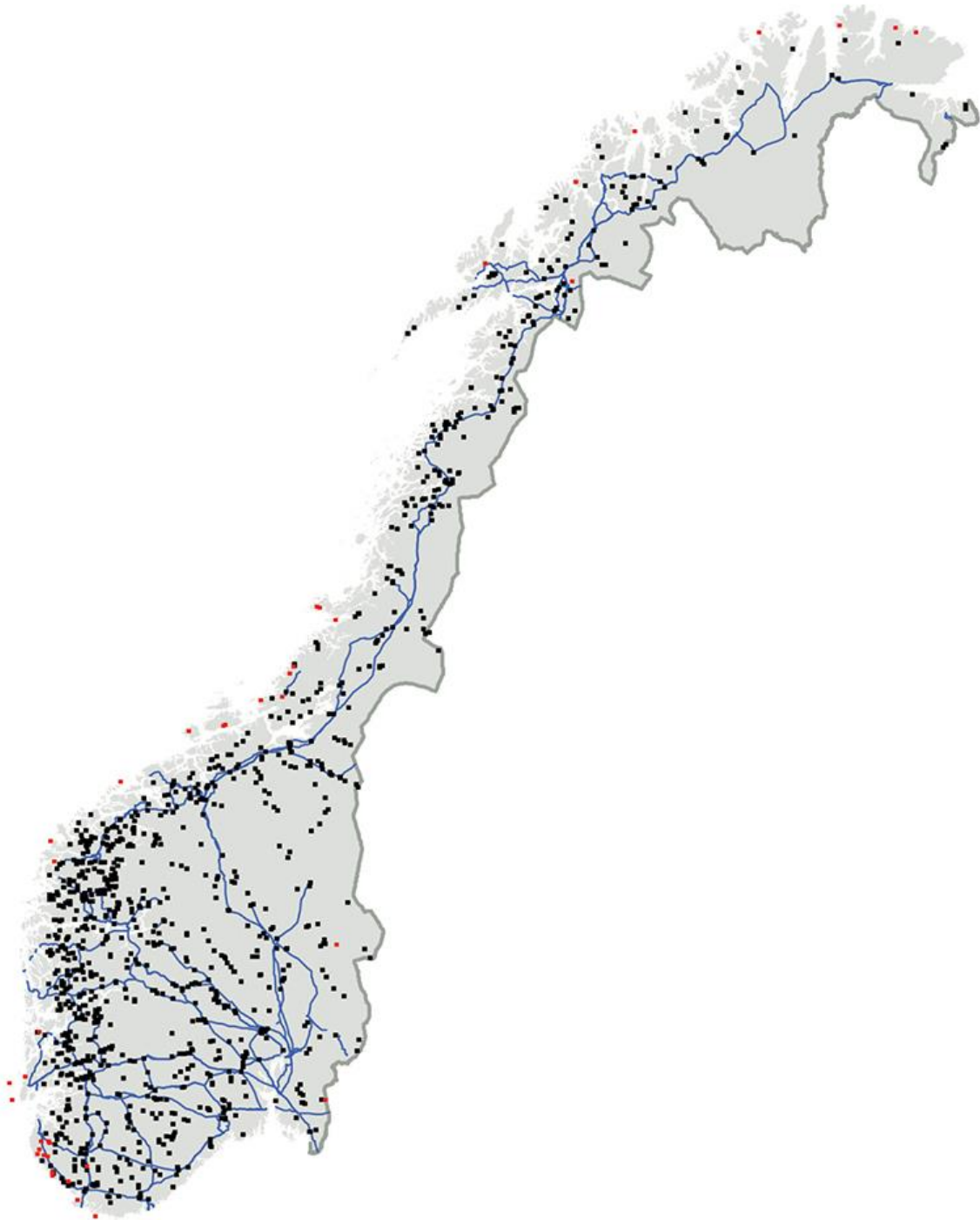


Figure 5.8 Hydroelectric power plants (black dot), wind turbines (red dot) and central grid (blue lines) in Norway

NVE Atlas, picked up April 22, 2022.

The hydropower makes the largest contribution, with an annual production of 137.9 TWh from 1739 power plants (as of 1.1.2022) (NVE, 2022). Wind power is the second largest technology, with an annual production of 15.4 TWh, distributed among 64 power plants and 1305 turbines (NVE, 2022).

There are 29 thermal power plants in Norway (as of 1.1.2022), and most of the power is produced at Melkøya and Mongstad. Thermal power generation is independent of the weather, and the actual annual production has been 3.5 TWh in recent years. (NVE, 2022). The most important energy sources in thermal power generation are natural gas, heat recovery, waste incineration and bioenergy.

In addition, many power plants are so small that they are not covered by national overviews or who are not affiliated with the power grid. This applies, for example, to some very small hydropower plants, and many solar power plants.

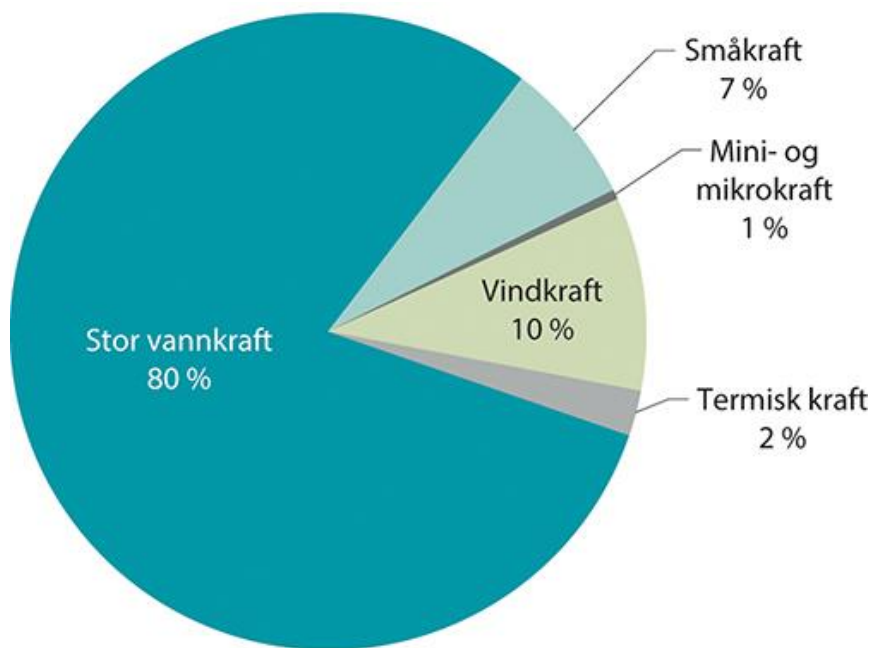


Figure 5.9 Percentage of power generation in a normal year in Norway, distributed on sources NVE.

Power generation varies widely with the weather. The inflow of the hydropower system can vary by 76 TWh. Year production from wind power and solar power also varies, by +/- 15 per cent. A detailed discussion of the variation is given in Chapter 8.

In particular, hydropower, wind power and solar power are the mature renewable technologies, which are also the ones that exist to some extent in Norway. Other technologies are under development, see discussion in Chapter 10.

### 5.2.2 Hydropower, wind power and solar power

The renewable technologies have different characteristics. Hydroelectric power plants with regulatory reservoirs can store energy, and bioenergy can also be stored. Otherwise, renewable energy is unregulated and produces according to weather conditions.

Hydroelectric power plants can be regulated or unregulated. The unregulated power plants, also called river power plants, have an intake where the water is led away from the river in pipes or tunnel to the power station. The water is then returned to the river, to a lake, a magazine or the sea. Such power plants produce after the inflow.

Regulated power plants have a magazine, which is an artificial or natural lake where the water level can vary within boundaries laid down in the licenses. Magazines are available in all sizes, and some have a storage capacity that is larger than the inflow coming during a normal year. Such are called multi-year or dry year reservoirs.

Norwegian hydropower magazines have a storage capacity of 87.3 TWh (NVE, 2022). NVE's magazine statistics include the 489 most important hydropower magazines. These stand for the essential of the storage capacity for Norwegian hydropower plants. In addition, there are over 900 other water regulated for power purposes. There is great variation in the size of the hydropower magazines, and the overall storage capacity in the hydropower system is distributed among many magazines.

In principle, regulated hydroelectric power plants can produce power when the owner decides it, and one does not depend on the inflow. At the same time, there may be restrictions on how the magazine is disposed of (eg requirements for summer water levels at a certain level of environment, user interests and aesthetics) and on how the power plant is run (eg, volume and variation in water flow out of the power plant ). It is also very varied which regulatory degree the power plants have. This is calculated as the magazine volume divided into the inflow for a normal year. Magazines have more functions than storing water for power generation. In particular, hydropower magazines are important for flood damping.

Hydropower is also divided by size. The smallest hydropower plants, with an installed power below 10 MW, are called micro, mini and small power plants. Large hydropower plants are those with installed power over 10 MW. Small power plants are usually without regulation, and are thus river power plants.

Pump power plants are hydroelectric power plants that can both pump water into the magazines and produce power. Such power plants are quite common in the Alps, where they play a role in balancing high day consumption and lower night consumption. With more unregulated power generation, there may be periods of very low prices, which pump power can utilize in anticipation of higher prices. In this way, pump power will contribute to more stable prices. In Norway, there are currently few such power plants, but there are some pumps that can move water from an intermediate level up to a higher -lying regulated magazine.

Hydropower has been expanded in Norway since the late 1800s and until today, and there are hydroelectric power plants in over 250 Norwegian municipalities. There is hydropower production in all parts of the country, but a lot of production is concentrated around the high mountain areas in southern Norway and in Nordland. Troms and Finnmark have a small proportion of production, and Vestland is the county with clearly the largest power generation from hydropower.

Although there are many small power plants in Norway, the largest power plants account for most of the production. The approximately 150 power plants over 50 MW account for over 100 TWh of normal -year production.

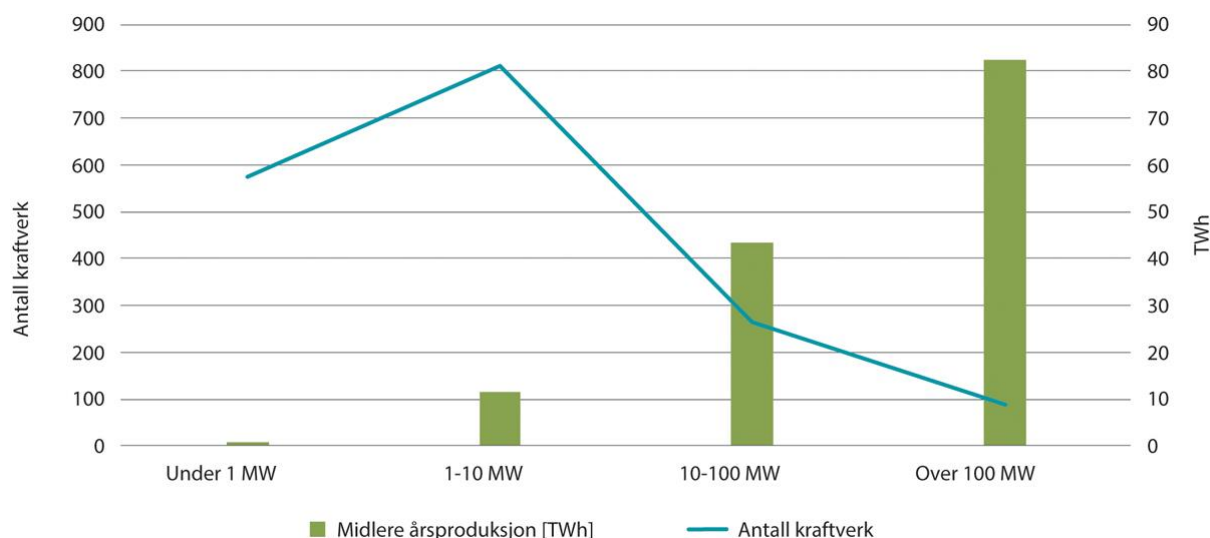


Figure 5.10 Number of power plants by size and total annual production (TWh) for each size category

NVE (2022).

There is continuous development in hydropower, and it is invested in both upgrading and expansion projects, new hydropower plants and in maintenance. At the start to 2022, there were 53 hydropower projects under construction, in both small power, renovation and expansion and new, larger hydropower. In total, these projects will provide new power generation of 1.3 TWh annually. (NVE, 2022).

Table 5.1 The largest power plants in Norway, by annual production

Kraftverk	Kommune	Ytelse [MW]	Årsproduksjon [TWh]	År satt i drift
Tonstad	Sirdal	960	4,4	1968
Kvilldal	Suldal	1240	3,6	1981
Aurland I	Aurland	840	2,5	1973
Svartisen	Meløy	600	2,5	1993
Tokke	Tokke	430	2,3	1961
Rana	Rana	500	2,2	1968
Sy-Sima	Eidfjord	620	2,2	1981
Nedre Røssåga	Hemnes	350	2	1955
Aura	Sunndal	290	1,9	1953
Brokke	Valle	330	1,6	1964

NVE (2022).

Wind power has gone from being marginal to becoming a significant type of power generation in Norway. Wind power technology is still under development, and the turbines have gradually increased. Today, wind turbines account for approx. 10 per cent of power generation in Norway in a normal year.

The wind turbines in Norway are essentially built over the last ten years. Most are located along the coast, and many in southwestern Norway and in Trøndelag.

As of April 1, 2022, there were four wind power projects under construction in Norway. The licensing treatment of new wind power projects was put on hold after the consultation of NVE's proposal for a national framework for wind power on land in 2019. The break lasted for three years, and in April 2022 the government opened up for licensing where the host municipalities agree to it. The treatment of new projects will be based on the changes and considerations that follow from the wind power report and the Storting's treatment of it (Ministry of Petroleum and Energy, 2020) (Storting's Energy and Environment Committee, 2020).

Sea wind power is at an early stage in Norway. Two floating wind turbines have been online at Karmøy. The oldest is the pilot project for Equinor's Hywind concept, which was put into operation in 2009. The turbine has now been taken over by Unitech and is continued under the name Zefyr. The second turbine is the Tetraspar demonstrator, which was put into operation in the summer of 2021. Metcenters in Karmøy, which hosts tetraspares, are planning to demonstrate the demonstration of several liquid turbines.

In 2022, the floating wind turbine Hywind Tampen was put into operation on the Snorre and Gold Fax platforms. The wind turbine, which is 94.6 MW distributed over eleven turbines, will supply part of the power of the petroleum installations. The Hywind Tamp should not be connected to the power grid on land in Norway.

Two areas for wind power have been opened on a larger scale in Norwegian marine areas, southern North Sea II and Utsira Nord. The regulations for offshore wind power are under development. The announcement of land in the two areas has been notified in the first quarter of 2023, with allocation later in the year.

At the start to 2022, there was 186 MW solar power associated with the network in Norway. This installed performance provides an annual power generation of 0.15 TWh, or around a per thousand of total power generation in Norway. Some solar power plants are not connected to the grid, and if one includes them, then the total installed performance is more than 205 MW.

Around five per cent of the solar power plants are larger than 50 kW and account for half of the production. (NVE, 2022).

In 2022, NVE granted a license to the first ground-mounted solar power plant in Norway - Furuset solar power plants in Stor-Elvdal municipality. The solar power plant will receive a performance of 7 MW and has an expected annual production of 6.4 GWh. The plant will cover around 175 goals (NVE, 2022).



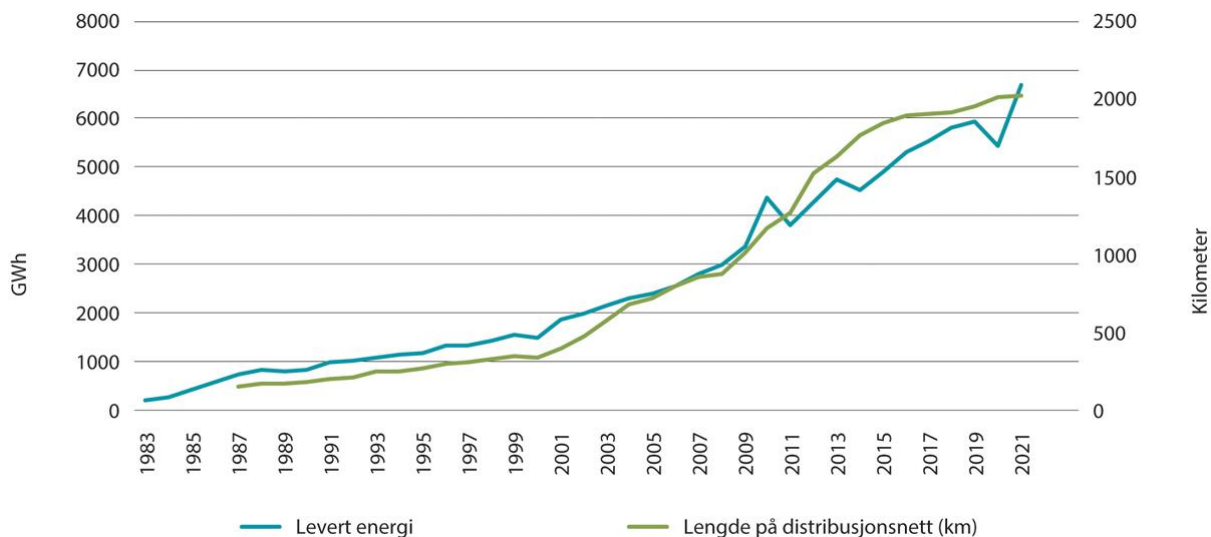


Figure 5.11 Development in delivered energy (GWh) and the extension of the wiring (km) for district heating in Norway

Statistics Norway.

The cost trend for renewable energy production and the prospects for development within the various technologies are discussed in Chapter 10.

### 5.3 District heating

District heating and remote cooling are supplies of heating services to consumers from larger central units that have flexibility in the choice of heating and cooling sources. Compared to our neighboring countries in the Nordic countries, district heating is not widespread in Norway. This is partly due to the fact that Norway has had ample access to electricity from hydropower to a relatively low cost.

Nevertheless, there has been a development of district heating in recent decades, including to ensure utilization of heat sources, to contribute to energy restructuring and to reduce the load on the power grid. Figure 5.12 shows that district heating is based on a variety of energy sources. The plants can also switch between energy sources to take advantage of varying energy prices.

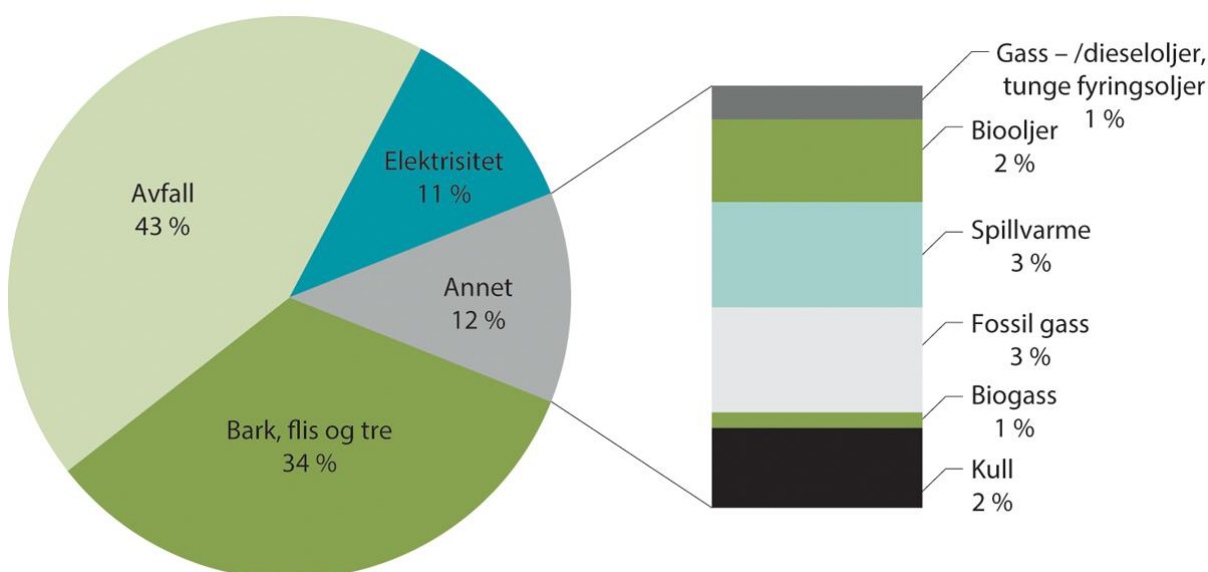


Figure 5.12 Energy sources used for the production of district heating in 2021, percentage distribution

Statistics Norway.

In 2021, 6.7 TWh of district heating and 0.2 TWh remote cooling (Statistics Norway, 2022) were delivered. The consumption of fuel and surplus heat to produce district heating was 9.2 TWh. The use of district heating is eight times larger today than in 1990, but still covers no more than about two per cent of Norway's total energy consumption. District heating covers about a tenth of the need for room heating and heating for tap water in Norway. Installed power for district heating is approx. 3600 MW.

District heating and remote cooling require both access to energy and access to a market for heating services. A separate infrastructure is required to distribute district heating and remote cooling so that there must be some customer density to defend costs. District heating and remote cooling are therefore most widespread in larger buildings with high heat demands and in urban areas, but there are also some plants in connection with industrial areas.

District heating covers about 20 per cent of Oslo's heating requirements, and 25 per cent of the power requirement in Oslo can be covered by district heating (Ministry of Petroleum and Energy, 2022).

## **6 Climate policy provides direction**

Climate change is one of the main challenges of our time. The consequences are serious and irreversible. The UN Climate Panel IPCC has stated that the global average temperature has already increased by 1.1 degrees due to man-made greenhouse gas emissions. This requires that we must carry out immediate, extensive and persistent emission cuts in all sectors (IPCC, 2021). In particular, this will apply to energy production and consumption patterns: About 70 per cent of global greenhouse gas emissions are energy-related, making the energy sector a key sector for restructuring.

Climate policy is today the largest driver for the large-scale restructuring that the power sector has to go through, and electrification is the prevailing climate measure. This field is constantly evolving, and over time, climate policy has become both more sector-wide and binding. Major changes are also expected in the years to come.

Especially in the EU, climate and energy policy is moving rapidly. In Europe, large parts of fossil power generation will be discontinued and replaced by unregulated renewable power. Although Norway has an almost emission-free power supply on the mainland, the green shift with increased electrification will also be marked here. In addition, we are influenced by the surroundings around us-Norway is closely integrated into the European energy markets through the EEA Agreement, and the energy infrastructure connects to our neighboring countries through the Nordic power market, to the continent and to the UK. This makes us indirectly connected to other European countries. We are similarly closely integrated with Europe's climate policy, both in terms of ambitions and instruments. In the EU, energy and climate policy is increasingly closer to each other and will be further integrated in the years to come. This provides guidelines for the development of Norwegian energy policy.

### **6.1 The starting point for the EU and our neighboring countries**

Norway and Europe have different starting points for energy conversion. The political landscape and institutional features have an obvious significance, but one important difference is that the power systems are different.

The energy mix varies between land, but it is still the thermal power generation, also called heat power, based on coal, gas and nuclear power that dominates in Europe (IEA, 2020), see Figure 6.1. In most countries, thermal power accounts for well over half of electricity production, for some almost 100 per cent.

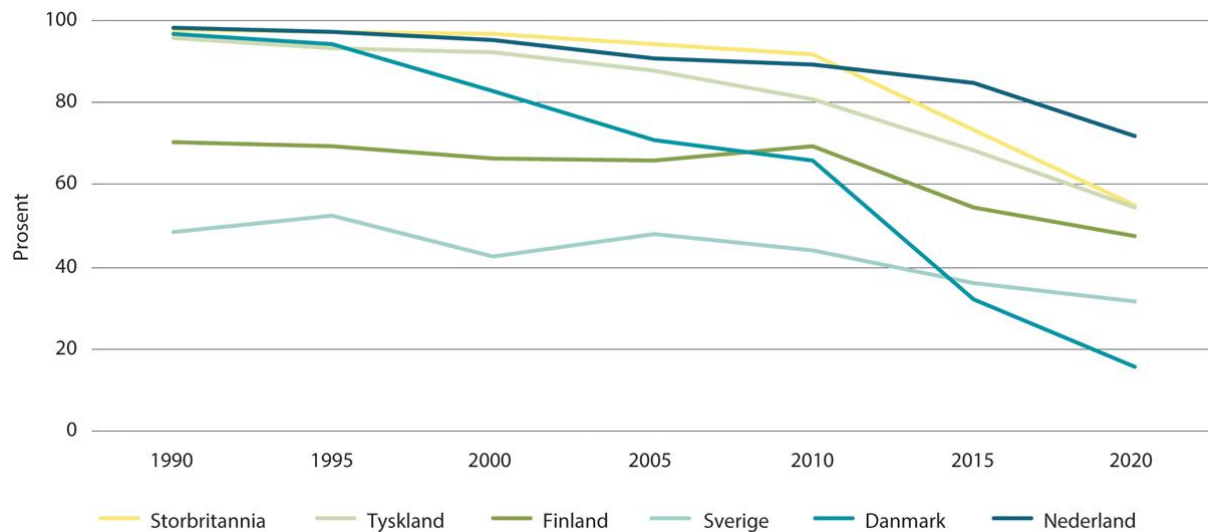


Figure 6.1 Percentage of thermal power generation in the countries around us 1990-2020, percent

IEA (2022).

Norway, on the other hand, has a renewable power system. The system differences have laid the foundation for how the Norwegian and European power systems interact through power trade. The hydropower is adjustable, and production can be adapted to rapid consumption changes faster than what a heat power plant can. Thermal power plants are most effective if run with even loads. This has provided favorable opportunities for power trade, see also chapters 4, 11 and 13.

When the composition of the power systems around us changes, it also means that Norway's interaction with Europe changes. The energy mix in the EU and our neighboring countries are moving away from thermal power generation, and is increasingly oriented towards renewable energy sources. This shift started in the 2010s, and by 2020 the renewable share in the EU had reached about 22 per cent (EEA, 2022). Despite the fact that growth has long been steady, especially in solar and wind power, the need is still high. The development is driven forward by the EU's climate and energy policy.

#### Box 6.1 Net Zero By 2050 - A Roadmap For The Global Energy System

The transition to a low -emission society requires an extremely ambitious transformation of the energy system, and requires a comprehensive, coordinated, fast and total restructuring worldwide. Only if all countries become climate neutral in 2050 can the world succeed in limiting global warming to 1.5 degrees.

In 2021, the IEA presented the road map "Net Zero by 2050: A Roadmap for the Global Energy System", which shows one possible path to how the energy sector can be changed to reach the climate goals. In the outlined scenario, two -thirds of the total energy supply in 2050 will be renewable, and much more diversified than today. It is assumed that most of the global emission reductions towards 2030 will come from production technologies that are already established, such as wind and solar and nuclear power. The scenario also requires a significant and immediate change of pace when it comes to energy efficiency worldwide. The

annual improvement of energy efficiency will increase by 4 per cent compared to 2030 - three times as much as in the last decade. As a result of extensive energy efficiency, energy consumption in the world will be 8 per cent lower in 2050 compared to today, although the world's population increases by 2 billion and significant economic growth is assumed.

By 2050, new technologies must also be rolled out that are not yet commercially mature. In the scenario, about half of the emission reductions comes from 2050 from these. This includes advanced batteries, hydrogen, and CO<sub>2</sub> management and direct CO<sub>2</sub> capture from the atmosphere. In the scenario, global energy investments until 2030 must increase by about 2.5 times the level in the last five years, and remain at a high level further towards 2050. Oil and gas demand is estimated to be reduced by 75 and 55 percent respectively in 2050 compared to 2020 levels. Therefore, in the scenario, the development of new oil and gas fields will not be necessary to meet demand. Coal is almost completely gone.

Furthermore, the change is about people-more people should have access to energy, and emission reductions must go hand-in hand with an effort to ensure energy access to everyone by 2030.

[Box End]

## **6.2 The EU's climate and energy policy**

The EU's climate policy began to move in the 1990s, and over time has evolved and expanded. Today, the EU's objectives in the climate area are very ambitious in the world context. The long-term vision is for Europe to become the first climate-neutral continent by 2050, and by 2030, greenhouse gas emissions will be reduced by 55 per cent compared to the 1990 level.

In order to regulate greenhouse gas emissions, the EU has developed a climate rules consisting of three pillars: the quota system, which has long been the flagship of the EU Politics (ETS), the regulations for non-quota emissions, (effort distribution regulation-EFFORT SRARD Regulation (ESR). and the regulations on accounting of emissions and recording in forests and other land areas (LULUCF). The pillars have their own ceilings for emissions, and together will contribute to the EU reaching the targets for emission cuts over time. The three pillars are described in more detail in Chapter 6.3.

In 2019, the EU's current target for emission cuts was launched through "Europe's Green Giv" ("European Green Deal"). The strategy will lead the way for the vision of a climate neutral Europe. The goal is to transform the EU to a sustainable, circular and climate-neutral economy by 2050. In the strategy, a wide set of instruments, sector-wide initiatives and significant tightening, such as a European climate law, updated 2030 goals, revision of the European system for quota trading were proposed. , and several concrete energy strategies. In the strategy, it is also a key point to facilitate green growth and fair restructuring.

In order to implement the goals of "Europe's green giving" in current legislation, the EU in 2021 launched the climate package "Ready for 55" ("Fit for 55"). The package contains proposals for new or revised regulations that are intended to ensure that the EU reaches its new climate targets on cuts of 55 per cent compared to the 1990 level by 2030, upgraded from the previous target of 40 per cent that the climate regulations are currently being aimed at.

This means that the three pillars of the climate regulations are revised, in addition to the Renewable Directive, the Energy Effectivation Directive, the Building Energy Directive and the Energy Satting Directive. Most sectors are affected.

The proposals under "Ready for 55" are being considered in the EU, and it is expected that the new climate regulations will be adopted in 2023 (Ministry of Climate and Environment, 2022-2023). However, the road for the EU restructuring is both changing and unpredictable, which we have experienced through the major events that have occurred only over the last couple of years. The biggest incident is by comparison war in Europe. In light of the major consequences of the energy area of the war in Ukraine, the EU has accelerated its energy conversion and reinforced its energy policy goals. In March 2022, the "RepowerEU" strategy was launched, with the goal of phasing out Russian fossil energy. The strategy is based on three parts: diversification of energy imports, energy saving and accelerating the development of more renewable energy (EU Commission, 2022). The main initiatives, in the short and medium term, are elaborated in box 6.2.

#### Box 6.2 Suggested main initiatives in RepowerEU

- Joint purchase of gas, LNG and hydrogen via the EU's energy platform.
- Form new energy partnerships with reliable suppliers.
- Increase the renewable share in the energy mix to 45 per cent by 2030, up from previous proposals for 40 per cent in the "ready for the 55" package.
- Rapid roll-out of solar and wind germ projects and simplify and shorten down the concession treatment for renewable energy. Renewable energy is appointed, among other things. With the status of "Overriding Public Interest", defined "go-to areas" will be created where there are good conditions for renewable energy and lower environmental risk.
- Launch of a solar strategy, including With 320 GW new solar power by 2025 (a doubling of installed capacity in 2020), and 600 GW by 2030.
- Launch of an energy saving strategy, including With proposals to increase energy savings from 9 to 13 per cent between 2020 and 2030.
- Develop plans for demand reduction for interruptions in the gas supply.
- Investments in an integrated and adapted infrastructure for gas and electricity.
- Measures to ensure the industry access to critical ingredients.
- Increase the production of biomethane.
- Regulatory development and measures for hydrogen.

(EU Commission 2022)

[Box End]

It is uncertain what will be the outcome and the long-term consequences of the EU's reinforced efforts, but have never had the restructuring in Europe had greater momentum.

Already in the late autumn of 2022, it was announced that the EU's climate targets may become more ambitious than they are today. During the COP27 climate summit, the EU Commission's climate chief announced that the EU will submit updated climate targets to cut emissions by at least 57 per cent by 2030 compared to the 1990 level (EU Commission, 2022). This is two percentage points more than the goal that the EU is already working to align its climate regulations in "Ready for 55".

The current situation, however, is that the absence of Russian gas has initially led to a step through increased need for coal, oil and LNG in Europe, as described in Chapter 3.

#### 6.2.1 The energy conversion in the countries around us

The individual EU member states may be drivers or brake pads for the Union's policy development. For Norway, it is especially important what the countries we are connected to and trade with do.

The power system in the UK has historically been dominated by fossil energy, with elements of some nuclear power. The country needs a lot of new renewable power to reach its goal of net zero emissions in 2050. In line with the Government's Energy White Paper (UK Government, 2020) and the plans to reach the net zero in 2050, Ten Point Plan for A Green Industrial Revolution And Build Back greens, the UK will still focus on nuclear power as an energy source. At the same time, the renewable energy mix will be diversified, and a combination of hydrogen, offshore wind and intermediate country compounds will be focused to ensure the decarbonization (Statnett, 2020). The UK is already one of the largest offshore wind countries, and more is under construction and planning.

In April 2022, the British government launched the strategy British Energy Security Strategy in response to increasing energy prices, high demand as a result of the pandemic and Russia's invasion of Ukraine. As in the rest of Europe, security of supply has become more important here as well. The ambitions are an even more ambitious and rapid expansion of renewable energy and hydrogen in order to phase out fossil power and safe their own long -term security of supply (British Energy Security Strategy, 2022).

In 2022, British authorities started work to assess whether the market design is suitable for the challenges that the transition to a renewable power system brings. The aim is to clear the energy conversion and at the same time safeguard the consideration of both energy security and reasonable prices (UK Department of Business, 2022).

Germany's "Energiewende" is the country's planned transition to a low -carbon and nuclear power -free economy. This has been a governing for almost a decade, and has produced clear results. Historically, the German power system has had a large element of thermal power, especially dominated by coal and oil, but today the energy mix is more diversified. Almost half are from renewable energy sources, including a large proportion of wind power.

The new German government has presented an ambitious plan to force the development of renewable energy sources. The renewable target is 80 per cent of gross energy consumption in 2030. A main feature is that the thermal in the long term should be phased out and replaced by especially wind and solar power. Germany is also investing heavily in the development of offshore wind, upscaling hydrogen production and phasing out the country's coal -fired power plant. At the same time, the Government will take regulatory measures, and shorten the time spent in planning and licensing of new projects (Winde Europe, 2022).

The gas use in Germany has long been covered through imports from Russia. Imports from Russia have been between 45 and 70 percent in recent years (IEA, u.). The restructuring of the energy sector is now under time pressure due to reduced Russian gas imports. Germany aims to become independent of the Russian gas. Since the invasion of Ukraine, the government has, among other things, presented new reform packages to develop more renewable energy rapidly (Clean Energy Wire, 2022).

The energy conversion is also fast in the Nordic countries. Although developments in total power generation and consumption by 2040 are uncertain, the political goals point to a large development of renewable energy in the Nordic region. There are differences between the countries, and the individual country's energy and concession policy affects what will be realized by new power generation over the next decades.

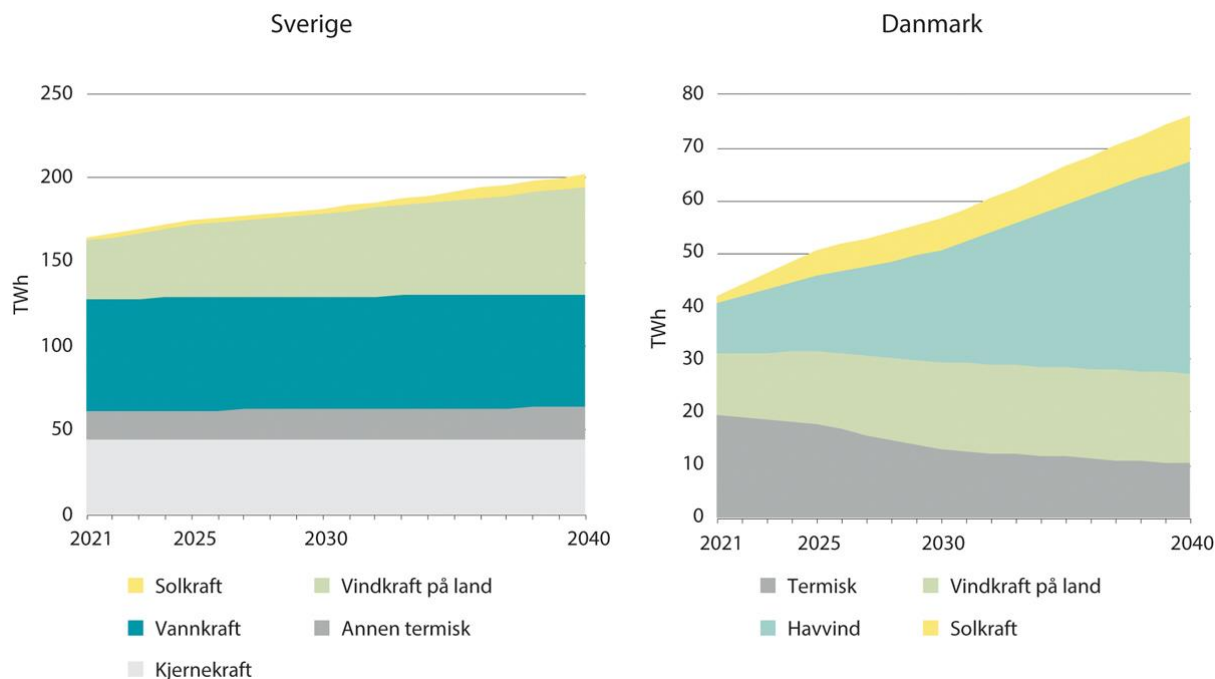


Figure 6.2 Power production in Sweden and Denmark 2021–2040, TWh NVE (2021).

Developments in Sweden are especially important for our power system, because this is where we have the most transfer capacity. Sweden's power generation is dominated by hydropower and nuclear power, where the latter is important to cover the base load in the Nordic power system.

In particular, the potential for expanding wind power in Sweden is large, but it is uncertain how much more will be expanded and where in the country it may come (NVE, 2021). When it comes to offshore wind power, Swedish authorities are pointing out new areas for development (the Ministry of Infrastructure, 2022). In 2022, a wider "wind power package" was also presented, with proposals for measures to increase the pace of land development and to investigate an allocation system for areas for sea power by sea (Ministry of the Environment, 2022).

Recently, the Swedish government has signaled that they want a new venture on nuclear power, including by reducing several of today's regulatory obstacles and introducing fast tracks for new nuclear power in the administration (Swedish Democrats, 2022).

NVE's analyzes (NVE, 2021) show that Sweden can increase power generation by 2040 and a significant surplus of power. At the same time, goals for phasing out fossil energy in the industry, together with the establishment of new industry, will be able to create a large need for power. This is especially true of battery factories and plans for electrification of the mining industry and the cement industry.

Denmark has had a thermal system based on coal and gas. This too should be phased out. There is a lot of focus on offshore wind power, and this will constitute a large part of the growth in new renewable production in the future, in addition to some solar power. There is expected high growth in electricity use (NVE, 2021). Danish buildings use a lot of district heating that comes from thermal power generation, and in the future Denmark wants to replace the fossil energy with large heat pumps powered by renewable electricity. Furthermore, the transport sector will be made fossil -free with a gradual transition to electric

cars. In addition, there are plans to establish data centers and hydrogen production from electricity.

The new venture from 2022, Denmark can more II (the Danish government, 2022) signals that renewable power generation in Denmark may be even greater than previous analyzes indicate. The Danish government wants to speed up the green change and become independent of Russian gas. Denmark aims to quadruple production of solar and wind power on land by 2030, and to enable a fivefold of power generation from offshore wind in the same period. The strategy has gained a broad majority in the Danish Parliament. Today, the Danish power supply is based on transfer from surrounding countries, including through the four Skageracables from Norway.

In Finland, bioenergy plays an important role in the country's power generation. Bioenergy today covers a high proportion of heating requirements in households and commercial buildings, and this is assumed to be continued. At the same time, the sectors that are most dependent on bioenergy become more energy efficient.

In addition to bioenergy, nuclear power plays an important role in Finland's power generation, and about a third of the country's electricity production has historically come from here. The nuclear power plants are expected to be important in the transition to a power system with increased variable power generation, but this depends on the phasing speed. Figure 6.3 shows how the capacity of the Finnish nuclear power plants develops if the reactors are phased out after the lifetime. This will halve the total performance as early as 2030 - 2040. However, there is little evidence that Finland wants to phase out nuclear power. It is heavily invested in getting the new nuclear power plant Okkiluoto 3 in operation after large cost overruns and delays as a result of technical problems.

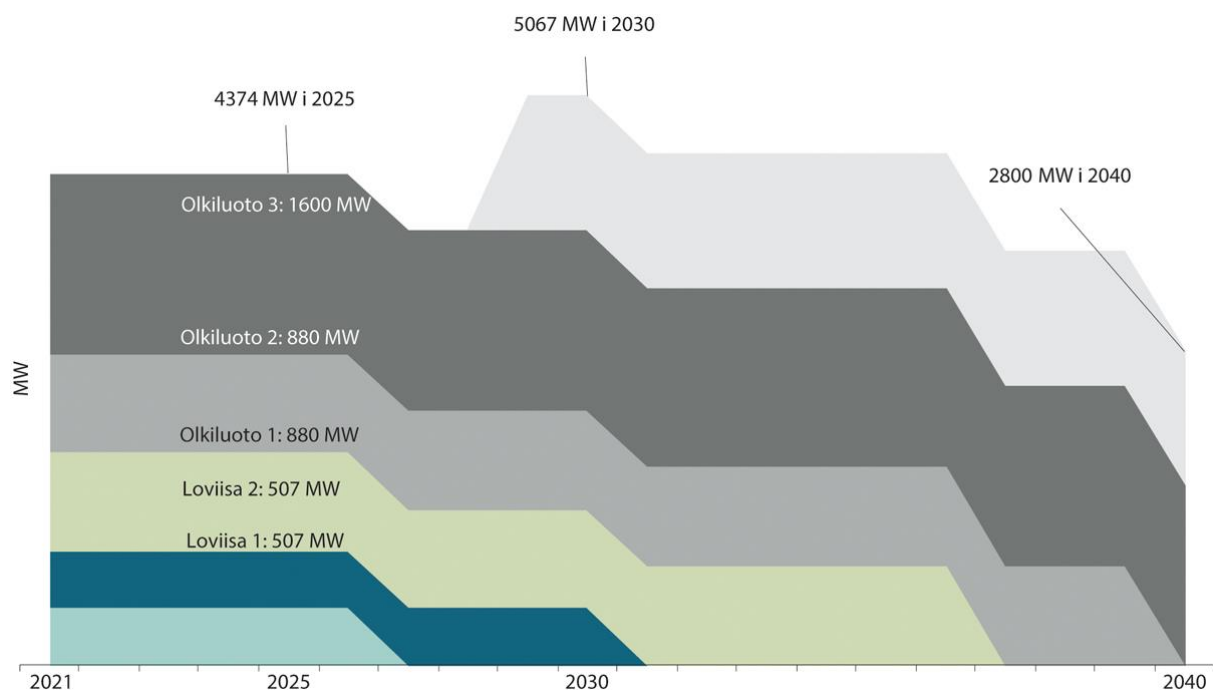


Figure 6.3 Performance in Finnish nuclear power towards 2040 at phase -out after the lifetime, MW1

1 as provided in NVE (2021)  
NVE (2021).



When it comes to the opportunities for the development of new renewable power, both the potential and interest in wind power are great. In line with the country's national energy and climate plan, a major development of wind power in Finland towards 2040 is expected.

Finnish power consumption may also increase due to electrification of the transport sector, and the establishment of data centers and hydrogen production. As Finland's power generation is expected to be at about today's level in 2040, the country is facing an increasing power deficit towards 2040 (NVE, 2021).

### **6.3 Norwegian climate policy - between Paris and Brussels**

International climate policy provides guidelines for our work in Norway and our objectives nationally. Our most important international obligations to reduce greenhouse gases are enshrined in the Paris Agreement, which we have agreed to. We have chosen this goal to cooperate with the EU to fulfill. In addition, through the climate agreement with the EU, Norway participates in the EU's climate regulations from 2021 to 2030.

#### **6.3.1 The Paris Agreement**

Norway, together with almost all countries in the world, has committed to cutting greenhouse gas emissions through the Paris Agreement. The Paris Agreement is the first global climate agreement to be legally binding and real binding (Ministry of Climate and Environment, 2021).

The aim is that the world in the second half of the century should be climate neutral. To achieve this, all parties under the Paris Agreement shall report a nationally laid down contribution every five years to limit greenhouse gas emissions. The contributions will constantly be reinforced and expressed the highest as possible ambitions for emission reduction (Ministry of Climate and Environment, 2021).

Under the Paris Agreement, Norway has undertaken, together with the EU, to reduce greenhouse gas emissions by 55 per cent in 2030 compared to the 1990 level. This is a reinforced climate target that was reported to the UN in November 2022. The previous climate target was emission reductions at the least 50 percent and up to 55 percent. Where and how the climate cuts are to be implemented must be seen in the context of Norway's climate cooperation with the EU.

#### **6.3.2 The climate agreement with the EU**

Through the EEA Agreement, Norway has participated in the EU system with climate quotas (EU EKS) since 2008. About half of Norwegian emissions are regulated by ETS, and include most of the emissions from industry, petroleum and aviation. Norway does not have its own goals for national emission cuts in the quota sector under the EEA Agreement, but the EU reduces the number of available quotas in the EU each year.

In accordance with the EU regulations, the emission target can be carried out flexibly. Explanations on emission units early in the period can be saved and used in recent years, and there is a limited access to borrow from future years or purchasing emission quotas from other European countries.

In 2019, Norway signed a climate agreement with the EU, which means that from 2021 we collaborate on a joint fulfillment of emission targets for 2030 through the EU's climate regulations with the three pillars. This means that we not only participate in the EU ETS as we have so far done, but also in the intervention regulation and the LULUCF regulations. In practice, Norway is therefore a full member of EU climate policy cooperation in the period up to 2030.

The effort regulation includes non-quota emissions from transport, agriculture, waste, energy supply, heating and fluorative gases, as well as some industry and petroleum. Emissions from these sectors are less suitable to be regulated through a quota system, and are therefore regulated through other measures such as taxes, fees or subsidies.

Norway's goal to reduce non-quota emissions is set to 40 per cent in 2030 compared to 2005. The obligation will be met through a binding emission budget for each of the years compared to 2030. The Norwegian emission target was associated with the EU's previous climate targets. As a result of the EU's reinforced climate goals and the work on revising the climate regulations in line with the "ready for the 55" package, Norway will probably need to re-evaluate the emission target.

The LULUCF regulation applies to land use, an area that differs from the other sectors in the greenhouse gas accounts because it includes both the recording of greenhouse gases and emissions. The regulation is aimed at managed forests, deforestation, Eastern forest, cultivated land, pasture and wetlands, as well as carbon in wood products. The goal is that greenhouse gas emissions from land use should not exceed the amount that is bonded-ie a net-zero obligation (Ministry of Climate and Environment, 2021).

So far, Norway has fulfilled its international climate obligations. However, emissions have hardly declined since 1990, because much of the goal achievement has been carried out by the fact that Norway has purchased quotas for emission reductions in other countries. As formulated in the Hurdals platform, it is the government's ambition to implement the emission cuts in Norway.

The EU's "ready for the 55" package will intervene in all three of the EU's pillars. This will affect Norwegian climate and energy policy. The EU regulatory changes overlap with both existing and planned Norwegian regulations, which allows them to play well together. At the same time, other parts of the package may create a need for changed practice or further regulations (the Environment Directorate, 2021). Only after the new climate regulations have been adopted can Norway engage in dialogue with the EU, and possibly on what conditions, the various parts of the climate regulations should be applied to Norway (Ministry of Climate and Environment, 2022-2023). The final consequences for Norway are therefore unclear.

### **6.3.3 National guidelines**

The climate goals we have committed to, and our cooperation with the EU for emission cuts, is integrated into Norwegian politics and legislation. The Climate Act (2017) constitutes the legal framework for Norwegian climate policy, and consolidates our obligation in the Paris Agreement. The law states that Norway will be a low-emission society in 2050, which means that we will cut greenhouse gases by 90-95 per cent from the 1990 reference year. This climate target has not yet been reported to the UN.

The climate goals commit the government to give the Storting a statement on status and progress in the work. Reporting will contain information on developments in greenhouse gas emissions and recording, emission projections, implementation of the statutory climate targets, sectoral emission paths for non -quota sector, the status of the Norwegian emission budget and work on climate adaptation. In Figure 6.4, the connection in the climate targets for 2030 is compiled, as of August 2022.

## Norges forpliktelser i Parisavtalen:

55 % kutt fra 1990-nivå

## Klimaavtalen med EU per i dag:

minst 40 % kutt fra 1990-nivå

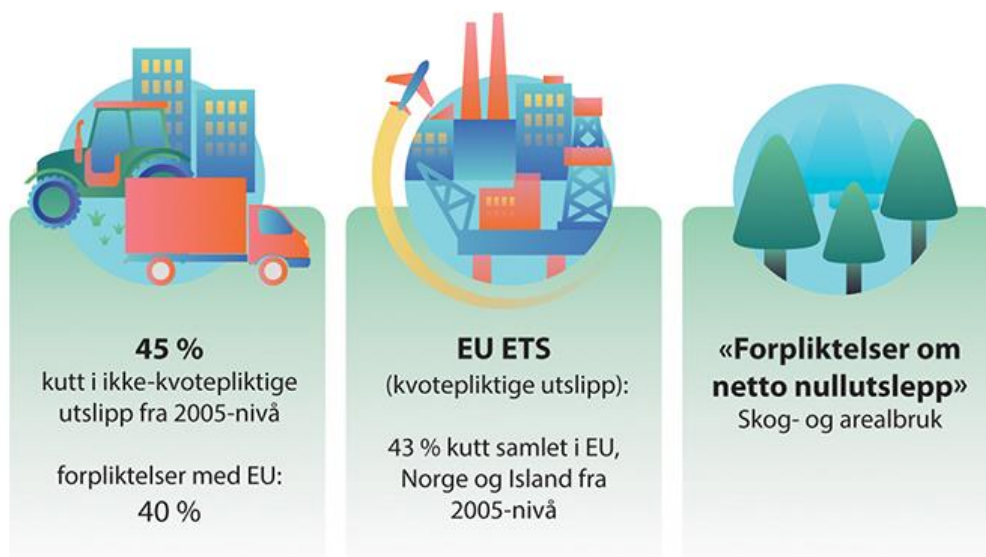


Figure 6.4 The connection in Norwegian climate targets for 2030  
Ministry of Climate and Environment (2022).

Through the work on Klimakur 2030 (the Environment Directorate et al., 2020) Various measures and instruments have been investigated that can result constitutes just over 40 million tonnes of CO<sub>2</sub> per year. This corresponds to an emission cut of more than 50 per cent.

Because Norway has a high renewable share in power generation, emissions must be cut in other sectors to achieve the goals we have set. Electrification is designated as the most important single measure and constitutes about 34 per cent of the total potential for emission reduction investigated in climate course. Climate measures to cut emissions in the non-quota sector therefore greatly affect the power sector. Implementation of the measures in Klimakur 2030 will require about 6 TWh more electricity than the Environment Directorate has used in the reference path for power use towards 2030 (Environment Directorate et al., 2020).

Meld. St. 13 (2020–2021) Climate plan for 2021-2030 explains how Norway will reduce greenhouse gas emissions by 2030 in line with the climate goals and in collaboration with the EU. Klimakur 2030 forms an important part of the knowledge base. The most important instruments in the report are greenhouse gas fees, regulations, emission quotas, climate requirements in public procurement and support for innovation, research and technology development. The main emphasis is on reductions in non-quota emissions. Figure 6.5 shows how the climate plan for various sectors together can help achieve a goal of 45 per cent emission reduction in 2030 compared to 2005, a goal set to over-fulfill the obligation that Norway currently has to the EU of 40 per cent.

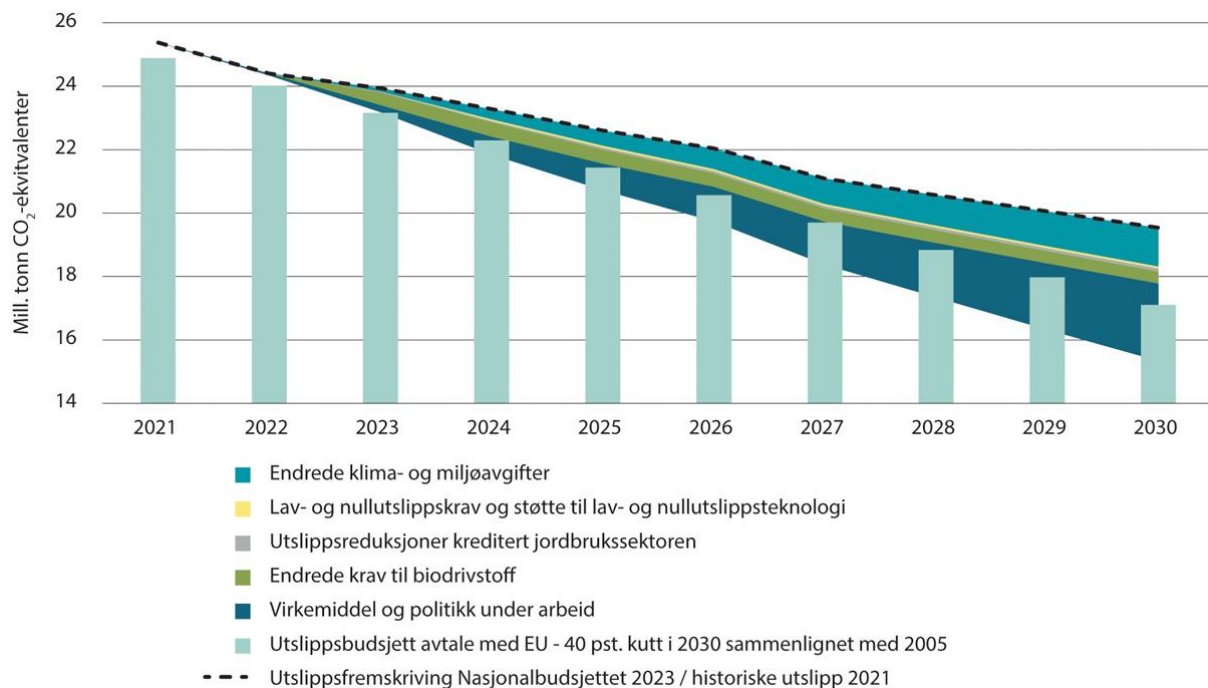


Figure 6.5 Emissions budget and expected emission reduction following the Government Klimaplan 2021-2030. Millions of Tonn CO<sub>2</sub> equivalents

Ministry of Climate and Environment (2020).

In order to investigate what road choices Norway is facing a low -emission society by 2050, the 2050 climate selection was set up in 2021. The committee will submit its report by November 1, 2023. In preliminary assessments from the summer of 2022, the committee highlights that good decision -making systems ensure stability, openness and openness and Predictable conditions, while providing flexibility to deal with unforeseen events and adapt to a new development. Good decision -making systems also help to give legitimacy to politics by ensuring that affected interests are heard. The Committee is currently considering that the decision-making systems we have today must better be adapted to the goal of a comprehensive restructuring of society (Ministry of Climate and Environment, 2022-2023).

In connection with the committee's work, the Environment Directorate has made new studies of the opportunities to reinforce the emission targets, and the power requirement that will accompany this. The study includes both quota and non-quota emissions. The analyzes show that it will require 24.4 TWh in increased power consumption in 2030 compared to 2021. The need may also be even greater - for example, the production of fuel with low emissions for transport will require another 10 TWh (the Environment Directorate, 2022). See discussion in Chapter 9.2.4.

## **7 The glass ball: About the future**

"It's hard to predict, especially about the future."

Storm P.

Uncertainty is something the decision makers in the energy sector have always lived with.

In the short term, there is uncertainty about energy access and power use, since both are largely dependent on the weather. The challenge is to operate the energy system with the facilities that exist in the most efficient way possible. In the disposal of hydropower magazines for a year, one cannot predict with certainty how much inflow power plants get, how much other renewable production is coming or how consumption will be. See Chapter 8 on the significance of the weather for power generation and Chapter 5 on the importance of power use.

In the longer term, it is about investing in new production facilities and networks based on expectations of consumption development. When decisions are made, it is uncertain, among other things, how much new consumption is coming, about societal cases for the construction of power plants and the network, the development of the countries we interact with, technology development, prices, and policies that affect all the factors. The goal of extensive and rapid restructuring from fossil to renewable energy sources in Europe and increased renewable production in Norway has meant that the uncertainty about the development in the future has become greater and much more complex than before, throughout the value chain.

### **7.1 Uncertainty in long -term power market analyzes**

Thema and Multiconsult (2022), on behalf of the Energy Commission, have mapped out which factors, or drivers, different analysis environments in Norway emphasize in their long -term power market analyzes until 2050. The survey is based on interviews and literature studies. The survey has gone mostly in the depths of Statnett's and NVE analyzes because they are important premise providers for many players, providing a benchmarking for other analysis providers.

The various long -term power market analyzes have different purposes and applications. The premises for the analyzes are important. For example, NVE's analyzes are based on today's specific instruments and measures, and what they believe is realized as a result. Statnett, for its part, assumes that energy and climate goals are achieved, and models what it takes to achieve the goals.

The survey shows which drivers the analysis environments regard as important for the development of the power sector in the long term, how they assess the uncertainty of the various drivers, and the properties of the models used to prepare the analyzes. The various drivers are closely connected and mutually affect each other. The model device is important to ensure consistent conclusions.

There is consensus among the analysis environments about what today appears to be the most important drivers for development, as well as which the highest uncertainty is the most uncertain. Everyone agrees that it is very important, and at the same time highly uncertain, how ocean -based wind power, hydrogen and green industry are developing. There are great ambitions for development in these areas, but it is uncertain how many of the projects are being realized and how quickly they will come.

On the power generation side, land -based wind power and hydropower are central technologies in the Norwegian context, while the sun is more interesting in a European context. The resistance to wind power on land and the dependence on societal matters creates

uncertainty about the further development of this form of production. Nuclear power can be a joker in both the Nordic and Europe. The production opportunities are discussed in more detail in Chapter 10. Chapter 9 describes the development of energy consumption.

Consumption flexibility becomes central to balancing the system when increasingly unregulated power generation is introduced in the power system. It is especially the flexibility potential from the industry that is highlighted as interesting because it can be a large volume, but this is also very uncertain.

The network development is highlighted as a particularly central driver. If a lot of new industry is to come, it is necessary to reinforce the grid, and for offshore wind power it is necessary to clarify how the network should be organized.

Fuel prices, including the CO2 price, to a large extent affect the price of power and are considered to be important for different players' decisions. Fuel prices are crucial in the short term, but the significance decreases as fossil energy sources are phased out of the European energy mix.

It is agreed that the political objectives at EU level give important signals. There is some disagreement about whether it is the goals themselves that are leading, or whether there are specific regulations, instruments and support systems that are most crucial in the analyzes. Several analysis environments assume adopted instruments in their analyzes, rather than more ambitious political goals.

The analysis environments believe that the Norwegian authorities can influence more of the drivers and help realize ambitions and reduce uncertainty. Concession policy is important and affects what production technologies are coming, the extent of developments and how quickly it is being built. How adopted climate goals and climate ambitions are followed up with actual instruments and framework conditions are of great importance. In Table 7.1, the importance and uncertainty of different drivers, in the short and long term, are summarized.

Driver	Kort sikt		Lang sikt			
	Viktighet	Usikkerhet	Viktighet	Usikkerhet		
Kraftkrevende industri	★★★	Utviklingen i Nord-Norge og Nord-Sverige er i fokus	Hvor mye og når?	★★★	Stållindustri i Nord-Sverige	Hvor mye og når?
Fornybarkapasitet	★★★	Landvind og sol er hovedfokus	Hvor mye og når? Værusikkerhet Volatilitet	★★★	Alle teknologier inkl. kostnader	Hvor mye og når? Værusikkerhet Volatilitet
Mellomlandsforbindelser	★★★	Prisforskjell nord-sør og import fra kontinentet	Hvor raskt øker kapasiteten nord-sør?	★★★	Likere priser, lavere volatilitet	
Fleksibilitet	★★★	Behovet for fleksibilitet øker	Værusikkerhet Volatilitet	★★★	Grønt hydrogen, fleksibelt forbruk nevnes som viktige bidragsyttere	Hvor mye og når? Værusikkerhet Volatilitet
CO2-pris	★★★	Produksjonsmiks med høy termisk andel	Hvor går prisen?	★★★	Lav termisk andel etter 2030	Hvor går prisen?
Brenselspriser	★★★	Gass mer enn kull	Hvor går prisene?	★★★	Mindre betydning når termisk andel minker	Hvor går prisene?

De fleste rapportene peker på politikk og regulering som viktige drivere, men disse antas som regel å ha en indirekte påvirkning ved at de andre driverne endres.

Figure 7.1 Summary of drivers, importance and uncertainty in the literature study in the short and long term

Multiconsult and Thema (2022).

All analysis environments acknowledge that analyzes of long -term development in the energy area will be uncertain. The uncertainty is largely handled through scenarios and sensitivity analyzes showing an outcome room. Most analyzes have an expectation scenario, and operate with a "high" and "low" scenario that assumes either persistent economic growth or sustained recession. The analyzes are often complemented by qualitative assessments and reasoning around the results. The available model device for the analyzes is generally considered good, but the quality of the data entered into the models varies. In particular, it is mentioned that data on consumption flexibility is challenging, especially related to industry, as this is information that the industry often does not share.

Several of the analysis environments note that results from the models must not be treated as a facet, but that they are intended to provide a basis for discussion. It is impossible to predict the future, and the models are primarily tools to show how different aspects are interconnected and can develop. Reference is made to Chapter 11 for a concrete review of any analyzes of power balance and prices until 2030 and 2050.

The competence in modeling the power sector in Norway is high, based on decades of experience with detailed modeling of the hydropower system and the power market. It can be questioned whether it is problematic that there is so much of consensus in the analyzes. There are pretty much the same type of models used, and it can provide a narrow outcome space in the analyzes. The players may not be good enough to "think outside the box" either. New measures are to a small extent "stress tested" in extreme scenarios with very low probability. One cannot dimension a power system based on the most extreme outcomes that are not very likely. However, such analyzes can be a useful tool for establishing strategies for crisis management and preparedness.

## **8 The weather like the engine in the power system**

Norway has always had a weather -based power system, where inflow to the hydropower system has varied between different years. The regulatory magazines help to smooth out the inflow variations, and many Norwegian power plants can thus produce power even during periods of low rainfall and low inflow.

Increased development of renewable power generation from wind and sun in Norway and Europe makes the power system more weather dependent. Unlike the adjustable hydropower, the energy from the sun and wind cannot be stored. The restructuring in the energy area can therefore be demanding, especially considering that it should take place at the same time as both power consumption and power requirements are expected to increase.

### **8.1 Typical weather patterns**

NVE has done an analysis of how the weather affects power generation and power consumption. The weather throughout Northern Europe is interconnected and often follows some well-known patterns. For example, a low pressure in the North Sea will provide a lot of wind power generation throughout Northern Europe, and rainfall leading to increased hydropower (NVE, 2020).

One of the most common weather patterns is characterized by low pressure in Iceland and high pressure over the Azores. Low pressure brings mild temperatures, with wind and rainfall in western Norway and in Nordland. Eastern mountains and in Sweden, on the other hand, there will be weather weather and low rainfall. In Germany and the United Kingdom it is often mild, dry, some sun and a lot of wind. It is dry and cold around the Mediterranean. Such a weather is typical in the fall and winter.

Another common weather pattern is characterized by high pressure over Northern Europe. It is called Euro-Atlantic Blocking. In the summer, this gives warm sun days with little wind in the Nordic countries. In Northern Europe it also gets warm and sunny, but some more village weather and wind. In winter, this weather pattern will give both the Nordic and Northern Europe a typical dry and cold winter day with a little sun. In Northern Europe, something will blow something, but almost nothing in the Nordic countries.

## 8.2 How the weather affects power generation and power consumption

The different weather patterns affect power generation and power consumption between years, seasons and throughout the day. There are also significant geographical differences in production, because Norway is an elongated country with different weather conditions. This means, among other things, that it often blows at different times in southern and northern Norway. Wind power production in southern Norway coincides more with wind power in other regions around the North Sea than in Northern Norway. When it blows a lot in southwest Norway, a lot of wind power is produced in the regions around the North Sea.

Hydropower depends on rainfall and inflow that historically shows large annual variations. An overview for Norway for the period 1958-2016 shows a difference of 76 TWh between the year with the largest and least inflow. For the country as a whole is the 1960 year of the least inflow. The useful inflow was then 95 TWh. This event has a calculated repetition interval of 20-50 years. For an arbitrary twelve-month period, less than 95 TWh have been recorded for four independent events since 1958 (NVE, 2017). Years of low rainfall can be challenging for the Norwegian power system, even with large multi-year reservoirs that can store more than the inflow in a normal year. In dry years with little inflow, it is often the same situation in Sweden and Finland.

### Box 8.1 Variations in Hydropower Administration affect the system price in the Nordic

A large proportion of hydropower in the Norwegian and Swedish production system means that variations in inflow to the water reservoirs have a major effect on prices in the Nordic countries.

During periods of high hydropower, there is a great deal of power, and prices will normally go down. During periods of low rainfall and less inflow, prices will normally increase.

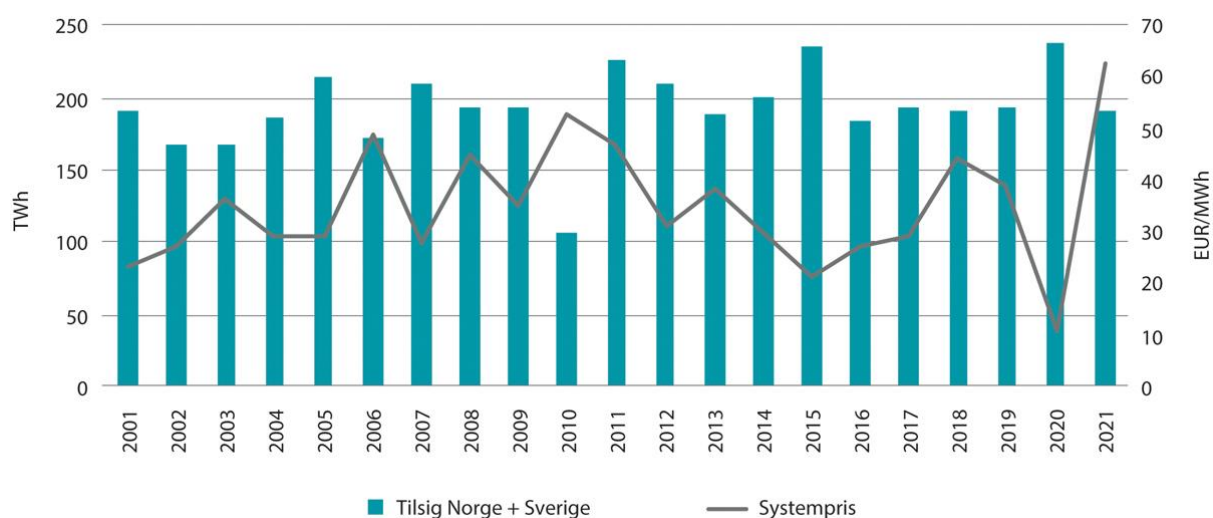


Figure 8.1 Hydroelectricity, TWh and System Price, EUR/MWh, 2001–2021



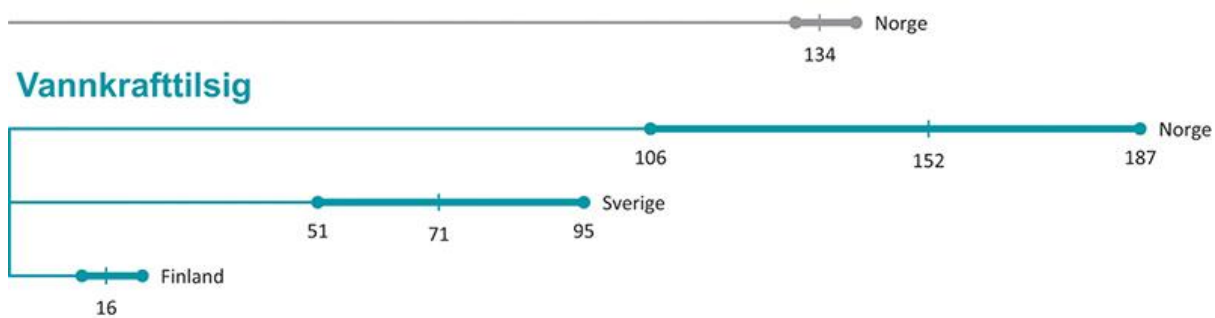
Nord Pool, Statkraft.

[Box End]

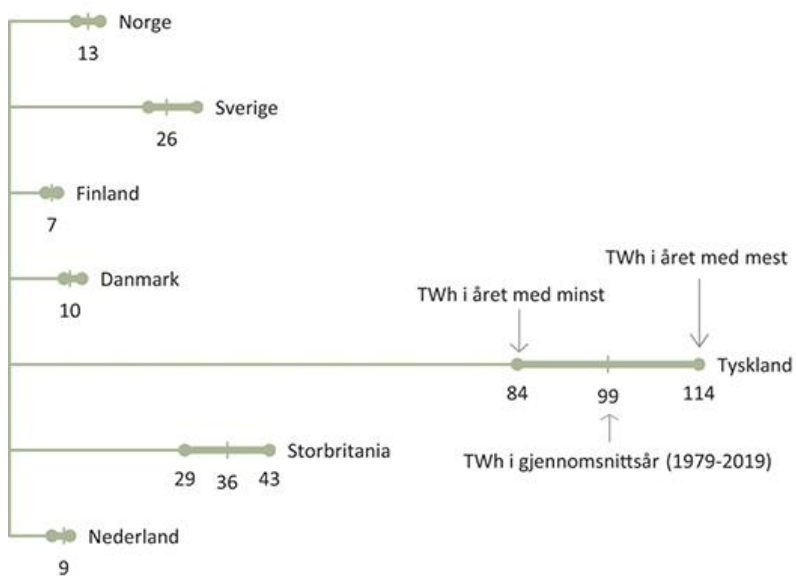
Similar weather in neighboring countries, combined with an increasing proportion of wind and solar power in all countries, reinforces the effect of the weather on the power system. Since the same weather type often characterizes large parts of Europe, variation in weather can lead to situations where there is either very much or very little renewable power generation, even over short intervals.

Figure 8.2 shows how power generation has varied over a 40-year period (1979–2019) for different production technologies in the Nordic and Land Norway has stopover. Only technologies with average production over 2 TWh/year are included. Power consumption is shown only for Norway (NVE, 2020).

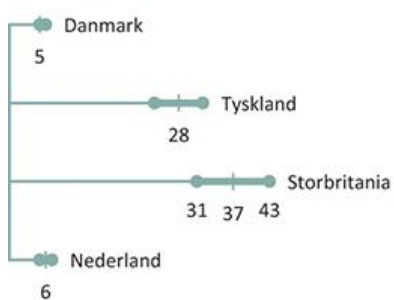
## Kraftforbruk



## Vindkraft på land



## Havvind



## Solkraft



Figure 8.2 Variation in annual power generation and consumption in TWh per technology for the Nordic and Country Norway has intermediate country compounds to NVE (2020).

For Norway, power consumption varies by approx. 3-4 per cent between the coldest and the hottest year in the period 1979-2019. In comparison, power generation varies between 12-30 per cent in the same period.

Since a significant proportion of ordinary power consumption goes to heating, this makes a large seasonal difference in the Norwegian consumption of electricity during winter and summer time. The power-intensive industry, for its part, has a smoother power consumption throughout the year.

Over the day, power consumption is lowest at night, while the top consumption is in the morning and in the afternoon. The 24-hour variation in power consumption is greater in winter than in summer and larger on weekdays than this weekend. Although power consumption varies throughout the day, there is also a large part of the consumption that is even as a base load, such as power consumption for industrial processes.

Power generation between different energy sources in Norway also shows a clear seasonal variation. In winter, large amounts of heat energy are moved from southern to northern latitudes in the form of wind. This means that it blows more in winter than in summer. The average seasonal profile for land onshore therefore coincides well with the seasonal variation for consumption. However, there is little blowing on very cold winter days when electricity consumption is also at its highest. Wind power on land and offshore wind has quite the same season profile, but offshore winds usually have a higher and smoother power generation than onshore wind power, since it is not affected by topographic conditions.

Dry and cold weather with little wind is typical when there is a high pressure over Northern Europe. During such periods, adjustable hydropower will play a very important role in maintaining the effect balance. Different geographical location of wind turbines in Norway can provide a more even access to wind power production, since it blows at different times north and south of the country (NVE, 2020).

### **Box 8.2 It always blows on the peaks, but not on the continent!**

An example of how the weather can drastically affect power generation in Germany at the beginning of week 46 in 2021. The week started with little wind on the continent, and German wind power production contributed less than 1 GW over several hours. In comparison, about 60 GW wind power is installed in Germany. During this week, German wind power varied by 35 GW within 3 weekdays (NVE, 2022).

Such situations are particularly challenging for the power system when the production failure is long-lasting or at the same time occurs over larger areas. This will make it more difficult to maintain balance between production and consumption in both Norway and Europe.

[Box End]

The inflow that ends up in the water reservoirs has an almost opposite season profile of wind. In the winter, the inflow is usually lower than the rest of the year, because it is cold and the rainfall settles like snow. The inflow is greatest in the spring when the snow melts. Throughout the summer, bresmelt contributes to the inflow. Wind power production, on the other hand, is on average at its lowest late spring and summer. In a seasonal perspective, therefore, wind power and hydropower complement each other well.

The value of the adjustable hydropower will increase in line with the proportion of unregulated wind and solar power being expanded. The great advantage of the adjustable hydropower is that it can be inserted and adapted to consumption if needed. Norway has half of Europe's magazine capacity, and more than 75 per cent of Norwegian production capacity is adjustable (Energy Switch Norway, 2022). River power plants that utilize the natural inflow also make a large overall contribution to power generation in Norway, but cannot be controlled according to consumption. The inflow is the lowest in winter when consumption is high. Large variations in the winter gap between different years increase uncertainty and make it more difficult to plan the operation of hydropower plants.

Polar power plants produce based on lighting conditions, and in Norway production is greatest in the summer. In the summer, when it blows less throughout the country, solar power can help to complement the wind power in a good way. The Meteorological Institute and NVE are embarking on a national survey of the sun resources. Preliminary calculations confirm that there are good opportunities to exploit solar energy across the country, but the best areas are located in southern Norway, especially along the outer Oslofjord and in the high mountain areas (Meteorological Institute, 2022).

When it comes to variations in power generation throughout the day, wind and hydropower have no regular 24 -hour profile, while solar power has a distinct 24 -hour profile because it is controlled by how high the sun is in the sky. Solar power contributes little in the top load hours, especially in winter.

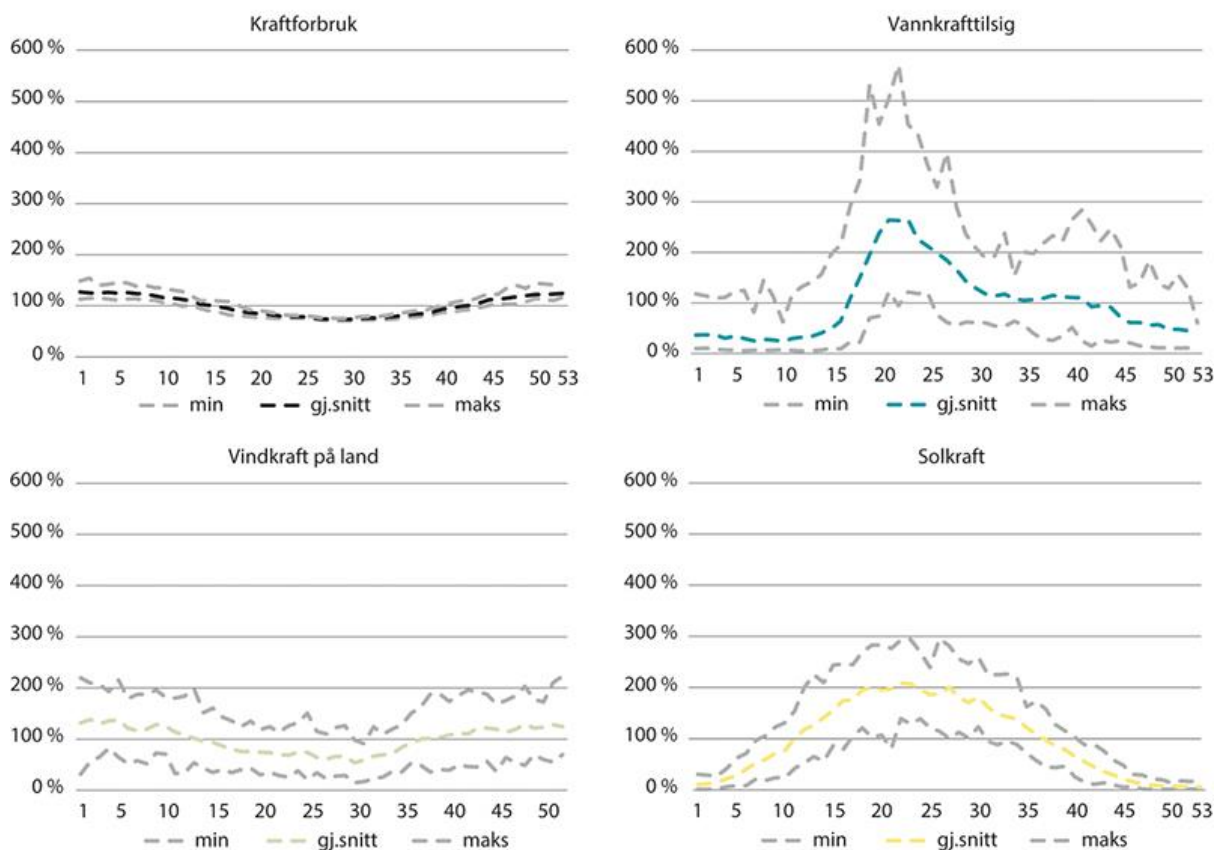


Figure 8.3 Percentage variation over the year in power consumption, hydropower, wind power and solar power in the period 1979-2019, percent<sup>1</sup>

<sup>1</sup> The dotted lines show historically maximum and minimum level in the same period. The profiles and outcome rooms are weekly data.

NVE (2022).

### **8.3 The effect of changes in climate**

In the future, a warmer and wetter climate will cause the total hydropower to increase in Norway. Most of the increase in the inflow can be utilized for hydropower production. On average, there will be more inflow in winter throughout Norway, but particularly major changes in Western Norway and Trøndelag are expected. The need to fill the magazines right up in the autumn is reduced as rainfall will increasingly fall as rain during the winter. The fact that the snow magazine is reduced on average, reduces the need to drain the magazines in the spring to make room for the snowmelt. The snow will come later and melt earlier. The snow magazines will thus have less significance (less energy will be stored as snow). The consequence of this is that you go from having a clear drainage with the snowmelt in the spring, to getting larger parts of the inflow during the autumn and winter (NVE, 2019).

The variations in the inflow from year to year will at the same time increase. Today, the winter gift can vary by around 26 TWh, while by the end of the century it expects it to vary by about 46 TWh. In the summer, there will be less inflow throughout Norway than we have seen in recent decades due to less glacial melt and increased evaporation.

Climate change means that manufacturers must adapt the maneuvering of the magazines to a changed inflow pattern to maintain flexibility and avoid flood losses.

According to the Climate Panel's fifth main report (AR5), a warmer climate will also increase the likelihood of longer and more extensive periods of drought in Europe. In Norway, climate projections show that the southern region is most exposed to drought (the Norwegian Climate Service Center, 2022). Long -term drought due to low rainfall and evaporation caused by high summer temperatures can cause deficits in field water and groundwater, thereby reduced inflow in the areas affected (Hisdal & Tallaksen, 2018).

The climate models show little or no change in mean wind conditions. For the highest wind speeds, there is an increase in all seasons. However, the model results are very uncertain when it comes to wind (NVE, 2022).

### **8.4 What can help reduce the vulnerability of a weather -dependent power system?**

A focus on several different renewable energy sources that interact to produce, store and distribute energy in a robust and secure way can help reduce the vulnerability of the power system. Energy University is a key word in this context. The possibility of exchange of power with other countries can also help increase security of supply, especially in dry years when the hydropower supply is much lower than normal. On the other hand, large exchange capacity can also help to weaken supply security if the water reservoirs are emptied to secure bottom loads to surrounding countries. Since power consumption and production capacity are unevenly distributed over the country, it is important to establish more production in deficit areas. It will also be necessary to ensure sufficient grid capacity between areas in order to cover deficits that cannot be removed through more local production.

The need for complementary production technologies, power exchange and an reliable and efficient power grid are further enhanced by climate change. The changes challenge the future power system through new weather patterns, changes in volume of inflow and distribution between seasons, as well as more extreme weather.

However, a rapidly increasing proportion of variable power generation from the sun and wind will make it challenging to maintain balance between production and consumption in all parts of the country at all times. Increased power requirements and more non-regulable power online increase the need for flexibility in the power system. In Norway, large parts of the

need for flexibility today are met by hydropower plants with magazines. The water reservoirs are central to a security of supply and a regulatory framework must be developed that ensures that they are disposed of in a way that provides sufficient energy and power balance this year with low inflow as well. Establishment of pump power in connection with existing magazines where possible can contribute to further flexibility. In addition, there will be a great need for new type of flexibility beyond the adjustable hydropower, such as batteries, hydrogen and consumer flexibility, see discussion in Chapter 9.

Today, Norway depends on wood burning for the power grid to withstand the coldest winter days. About half of Norwegian homes have a fireplace, and during periods of high electricity prices and cold weather, wood burning makes an important contribution to security of supply. Wood is the second most important source of energy in households, see discussion in Chapter 10.7. A new survey by Norstat conducted on behalf of the Norwegian Heating Industry Association shows that 340,000 Norwegian homes were given a new wood stove in the last two years. The same study also shows that around 700,000 Norwegians live in a home with a fireplace that should be replaced with clean -burning oven with less emissions and better effect.

## **9 Developments in energy use**

Power and heat provide services in society that provide prosperity and growth. We make goods of a quality, and to an extent, which would have been unthinkable without energy consumption. We shorten distances by car, boat, train and aircraft. Our weekdays are easier and filled with experiences. Energy use is not a goal, but a means.

We are in a situation where we will ensure that we still have a stable energy system, with safe access to electricity and heat, under changed conditions. The way we use energy is a crucial factor to succeed.

The use of power in Norway is currently around 138 TWh. According to NVE's and Statnett's projections, there will be an increase in the use of power of 21-30 TWh towards 2030, and 36-45 TWh towards 2040, partly as a result of measures to reduce greenhouse gas emissions and the establishment of new industry. Overall power use is expected to increase quickly towards 2030, and then more moderate towards 2040. All the analysis environments emphasize that there is great uncertainty associated with the projections.

### **9.1 Important Drivers for Development**

A number of drivers affect the development of energy and power use in Norway. The most important driver is the ambitious climate targets, which affect the Norwegian energy system both directly and through changes in the energy systems around us. All sectors that use fossil energy products in Norway will replace these with electricity to a greater or lesser extent. New industry that is important for implementing the transition is in emergence, such as the production of batteries, hydrogen and the establishment of data centers. It is the industry that is necessary to realize more automation and digitalisation, and that in itself can result in a large increase in the use of power.

Population growth is a driver for increased energy consumption in households and service sector, where most of the energy consumption takes place in buildings. Energy efficiency limits consumption growth in buildings, and the proportion of energy consumption that goes to heating will over time decrease because housing and commercial buildings become more energy -efficient. Increasing use of district heating and other heating solutions can reduce the use of electrical energy for heating. There is little fossil energy use left in the building sector.

The transport sector still largely uses fossil energy products. The future use of power in this sector is affected by emission targets, instruments for restructuring to renewable energy products, and technological development. Restructuring of the transport sector will involve a lot of electrification. Some of the energy consumption for transport can be expected to be covered by energy products such as ammonia, hydrogen and synthetic fuel, but the production of such fuel can increase the demand for electricity.

While the development of energy consumption in buildings is gradually taking place, industrial establishment involves jumping consumer increases. Industry's future power demand is the most uncertain factor in all projections of energy consumption. The types of industry to come, and to what extent, will depend on many factors, such as grid capacity and other infrastructure, power prices, access to area and freshwater, expertise and labor.

However, the projections of the energy consumption that were referred to were made in 2021. During the autumn of 2021, power prices increased sharply, and with the war in Ukraine the price growth became rapid and violent, see chapters 3 and 11. This crisis can make lasting changes in the markets, and Creator New uncertainties in the assessments that are not taken into account in the long -term energy market analyzes that existed before the crisis.

For example, the survey by Vista analysis and DNV, on behalf of the Ministry of Petroleum and Energy, suggests that the price elasticity is greater than previously expected (DNV and Vista Analysis, 2022). The temperature-corrected electricity consumption in households in southern Norway dropped significantly from the winter of 2020/2021 to the winter of 2021/2022. So did the consumption in holiday homes. There is reason to believe that this is related to the high price level in southern Norway.

## **9.2 Rooms for the development of the use of power**

### **9.2.1 How high will the use of power?**

The analysis environments are in agreement in their expectations that power use will increase significantly by 2030.

NVE's latest long -term power market analysis was done in 2021 (NVE, 2021) and is valid for 2030 and 2040. Towards 2040, NVE finds in its base scenario that power use increases from 138 TWh in 2021 to 174 TWh.

Statnett's latest long-term analysis applies to the period 2020-2050 (Statnett, 2020) and was updated in July 2021 (Statnett, 2021). In Statnett's basic scenario, the use of power increases from approx. 140 TWh in 2020 to 185 TWh in 2040. In the updated analyzes of 2021, Statnett uses the EU's target for a 55 percent reduction in greenhouse gas emissions by 2030, and that Europe reaches the 2050 emission targets. They expect the increase in the CO2 price to continue. By 2050, Statnett has a larger outcome room for the development of power use, because the consumption plans are less concrete far ahead. Development also depends on how much activity in the petroleum sector is reduced in the long term. In a short -term power market analysis (Statnett, 2022), Statnett provides an update on changes they expect in the near future.

Figure 9.1 and Table 9.1 show the outcome room for growth in the use of power. Statnett's analysis extends to 2050, while NVE's analysis stops in 2040. Both projections show a significant increase in the use of power. In the figure, DNV GLS, Themis and Process21's projections of the use of power are also represented, see also Chapter 9.2.4. DNV GLS, Process21s and Statnett's high track show the largest increase in power use towards 2030 and towards 2050.

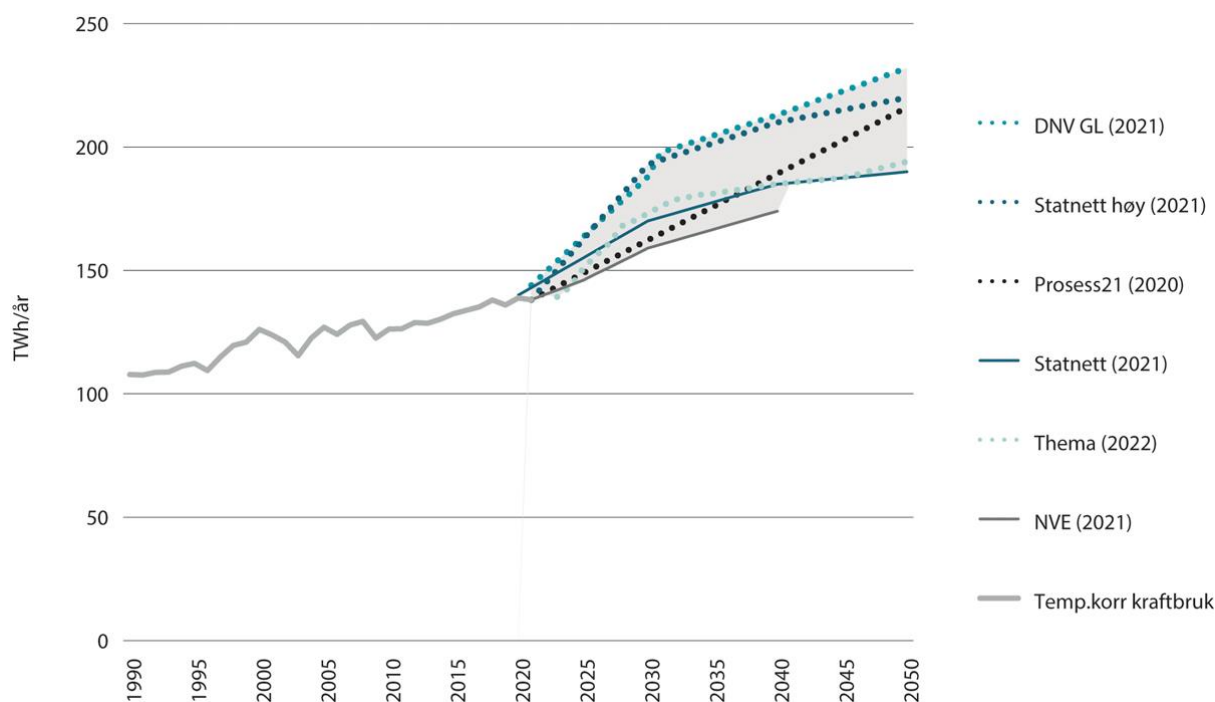


Figure 9.1 Outcome room for projections of power use in 2030, 2040 and 2050, TWh/year NVE (2021), Statnett (2021), Thema and Multiconsult (2022), DNV GL (2021), Process21 (2020).

The differences in the projections of the use of power are largely related to the fact that the analysis environments have different input to the analyzes. Some environments, such as NVE, have used adopted instruments in the calculations. Other environments, such as Statnett, have assumed that the countries reach their emission targets for 2050. There seems to be a consensus that it is not possible to reach adopted climate targets with existing instruments. The analysis environments also have different expectations of how quickly new industrial activity is established and how extensive growth we see.

Table 9.1 Projections of power use1, TWh.

	2020/2021	2030	2040	2050
NVE (2021)	138	159	174	
Statnett (2021)	140	172	183	190
DNV GL (2021)	144	188	213	232
Prosess21 (2021)	134			216
Thema (2022)		173	185	194

Some of the values are interpolated.

NVE (2021), Statnett (2021), DNV GL (2021), Thema (2022) and Process21 (2020).



I etterkant av at Energikommisjonen har gått gjennom disse analysene har Statnett oppdatert sin kortsiktige markedsanalyse for 2022-27 (Statnett, 2022) og DNV har publisert Energy Transition Norway 2022 (DNV, 2022). The new projections show higher expected consumption growth.

### 9.2.2 Where will consumption growth come?

In NVE's long-term analysis, the increase in power use in industry and transport takes place. Electrification of existing industry and the emergence of new industry, such as data centers and battery factories, accounts for 16 TWh of the increase. Production of hydrogen, among other things, for transport and industrial purposes, accounts for 7 TWh. Electrification of the petroleum industry provides approx. 6 TWh Increase in power use in 2040. Power use for transport increases by 13 TWh. I bygninger går derimot kraftbruken ned med 6 TWh i 2040 i forhold til i dag.

NVE peker på at økningen i forbruket i Norge trolig vil komme fra næringer som er relatert til energiomstillingen. Veksten i både eksisterende og nye industrivirksomheter er avhengig av blant annet nasjonal og global økonomisk utvikling, tilgang på ny kraft, kraftpriser og nettkapasitet. Veksten er dermed usikker, og NVE har derfor ikke lagt inn alle lanserte planer for industriutvikling i sitt basisscenario.

Statnett's analysis contains electrification of the existing industry, and the emergence of new industry, for increased power use of 22 TWh. Produksjon av hydrogen til blant annet transport- og industriformål bidrar til 8 TWh økt kraftbruk, og elektrifisering av petroleumsnæringen vil kreve ca. 7 TWh. Power use for transport increases by 12 TWh. The use of power in ordinary supply and buildings, on the other hand, goes down by 7 TWh to 2040.

Figure 9.2 shows the composition of consumption growth in NVE and Statnett's long-term analyzes.

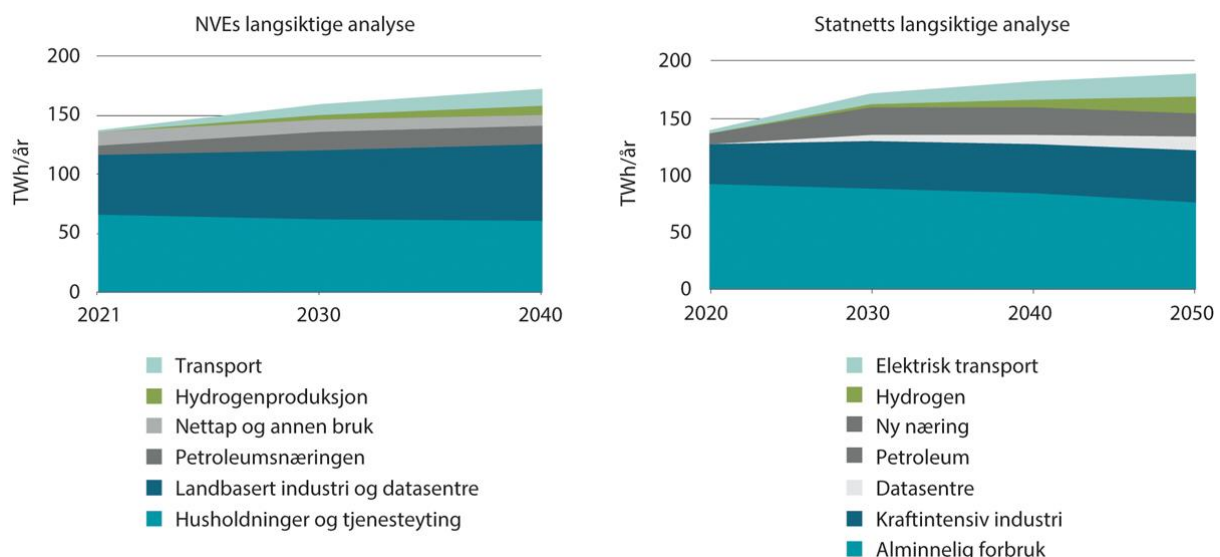


Figure 9.2 Nves and Statnett's projection of power use, TWh/year NVE (2021) and Statnett (2021).

In Table 9.2, the consumption changes towards 2030 and 2040 in NVE and Statnett's analysis are summarized. In NVE's projection, power use increases by approx. 21 TWh towards 2030,

while Statnett in its basic lane (Statnett, 2021) has an increase of over 30 TWh during the same period.

Common to Statnett and NVE is that they expect a decrease in power use in construction/general supply by 2030 and 2040, and a significant increase in transport, petroleum and industry.

Table 9.2 Expected changes in power use in 2030 and 2040, TWh

	2030		2040	
	NVE	Statnett	NVE	Statnett
Bygninger / alminnelig forbruk	- 4	-4	-6	-7
Transport	7	7	13	12
Elektrifisering petroleumssektor	6	10	6	7
Industri	12	19	23	30
<i>Hvorav hydrogen</i>	4	3	7	8
<i>Hvorav datasentre</i>	3	5	6	8
Nettap og annen bruk			-1	
SUM	21	32	35	42

NVE (2021) og Statnett (2021).

### 9.2.3 Other projections of the use of power

DNV GL publishes annual Energy Transition Outlook. Their projection is global and regional, and goes until 2050. On behalf of Norsk Industri, they have made a special projection for Norway (DNV GL, 2021). Here they outline an increase in power use of almost 44 TWh towards 2030 and nearly 90 TWh towards 2050. According to DNV GL, Norway is not able to reach the targets of 55 percent emission reduction in 2030 or zero emissions in 2050. They point out that much of the energy consumption in Norway is already decarbonized and that it is challenging to carbonize the rest.

Thema also prescribes power use (Thema and Multiconsult, 2022). Their basic projection is on par with Statnett's basic scenario, with 173 TWh in 2030 and 185 TWh in 2040. Thema expects a large increase in energy use in the industry.

Process21 has made an estimate of the use of power in 2050, and finds an increase of a total of around 82 TWh (Process21, 2020). Transport increases by approx. 19 TWh, electrification of the petroleum sector constitutes 15 TWh, existing industry increases by 25 TWh and new industry increases by approx. 25 TWh, see further description in Chapter 9.3.1. Heating and other consumption is reduced by 5 TWh.

In their energy policy platform, NHO and LO point to a possible annual use of power in 2030 at 170-190 TWh, given their ambitions (NHO and LO, 2022). This is an increase of 35-55 TWh. In their ambitions include an increase in industry, battery factories, data centers,

hydrogen, transport and the petroleum sector. Process21 and NHO/LO's estimates are significantly higher than what NVE and Statnett show in their basic scenarios.

#### **9.2.4 Climate policy and cuts in emissions provide increased power use**

Phasing out fossil energy products requires a sharp increase in the use of electricity. The framework for climate policy is complicated and changing. Several calculations have been made that illustrate how the measures to cut greenhouse gas emissions will affect energy consumption. These are not consumption projections, but the basis for developing policies to achieve the goals.

Most of the Norwegian greenhouse gas emissions come from industry, petroleum and transport. Figure 9.3 shows how today's greenhouse gas emissions are distributed among different sectors. The petroleum sector, including the business on the shelf and land-based activity, has a discharge of around 13 million tonnes of CO<sub>2</sub> equivalents, mostly on the shelf. Emissions in land-based industry are almost 12 million tonnes, and come from different types of operations, where aluminum and iron, steel and ferrole alloy are the largest. The majority of emissions in land-based industry are process emissions and a smaller proportion come from stationary combustion. Energy supply has emissions of slightly less than 2 million tonnes, most of which is from waste incineration and gas.

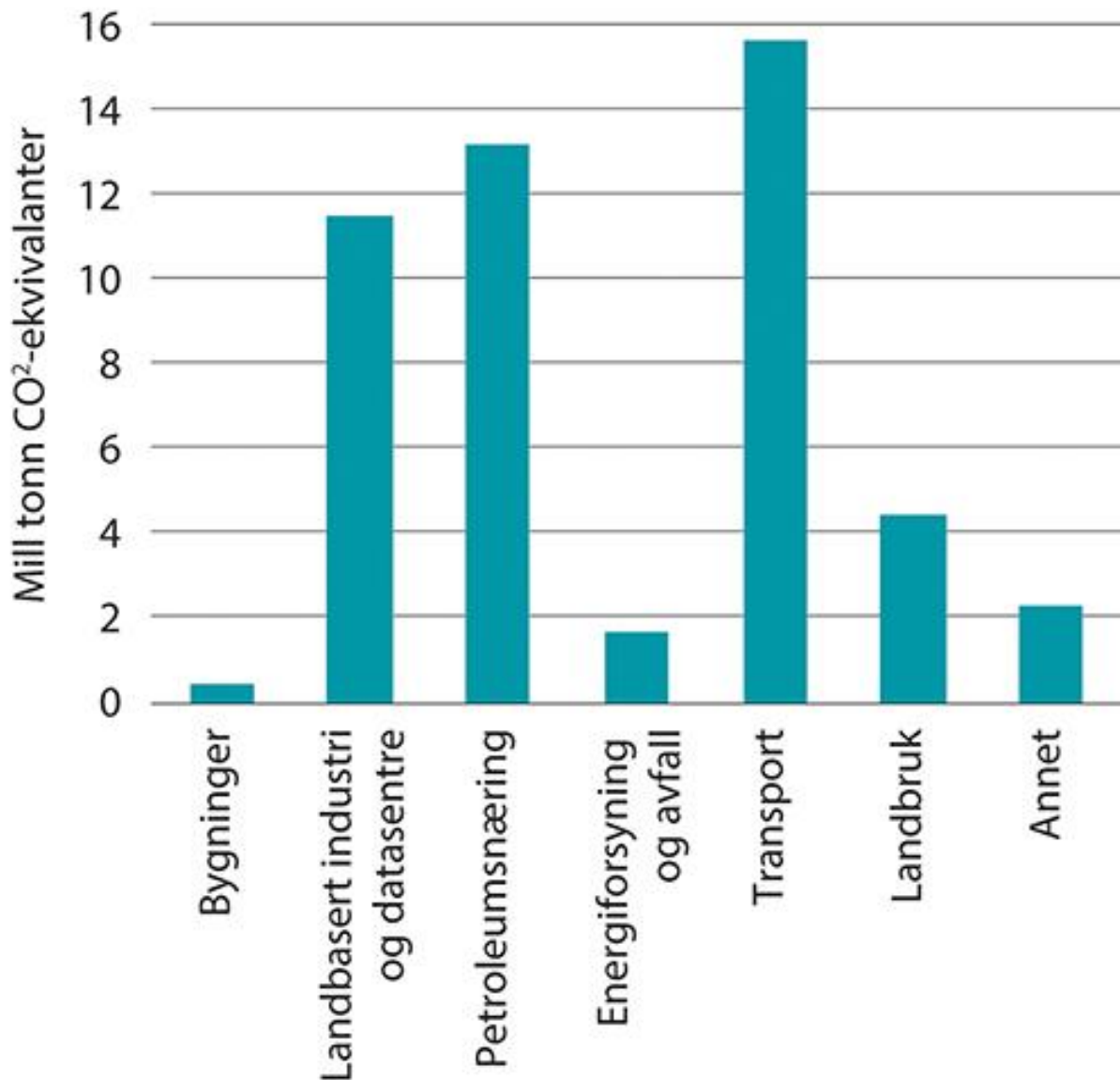


Figure 9.3 Emissions of greenhouse gases in various sectors, 2020, Mill. Tonnes CO<sub>2</sub> equivalents

Statistics Norway (2022).

The transport sector accounts for almost 16 million tonnes in emissions. Road traffic accounts for just over half of the emissions, and aviation, shipping, fishing and motor implements account for the rest. Emissions from buildings are 0.5 million tonnes. The emissions come from the use of gas and to some extent bioenergy. In addition, agriculture has over 4 million tonnes of emissions and "other" has 2 million tonnes (waste landfill, fluoride gases, solvents and the like).

In Klimakur 2030 (Environment Directorate et al Such an emission cut.

A public committee has been investigated how Norway will become a low -emission society in 2050. The committee will present its report by November 2023. In this context, the Environment Directorate has looked at emission reduction in petroleum, industry and energy supply, which accounts for a total of 26 million tonnes of emissions in Norway (Environment Directorate, 2022). The analysis includes both quota and non-quota emissions.

The Environment Directorate shows how emissions in land-based industry, energy supply and the petroleum sector can be cut by up to 67 per cent by 2030. The measures they point to are electrification, transition to hydrogen, carbon capture and storage (CCS) and the use of biocarbon. If all the measures in the analysis are implemented, they calculate that the use of renewable power will increase by 24 TWh compared to today. Land-based industry and energy supply will increase consumption by 14 TWh, and the petroleum sector will increase by 10 TWh. In the figures for the petroleum sector, the planned projects for electrification of the shelf include.

Implementation of the measures requires that many new industrial plants and new infrastructure be established. It will require large investments and strengthened climate policy. The Environment Directorate points out that power supply and power grids must be in place before the projects can be implemented. Time spent on this can push the implementation of the projects out in time. In addition, they point to a need for around 2 million fixed cubic meters of forest raw material and geological storage of 4 million tonnes of CO<sub>2</sub> in 2030.

It has not been possible within the Energy Commission's time frames to clarify how much of the measures the Environment Directorate has looked at which is included in other power market analyzes. It can be said to be a defect in Norwegian planning that the effects of the climate policy on the power system are not taken into account. Changes in the power system have a long lead time, and the power system can become a barrier to climate policy if the system is not dimensioned for the need for power and networks that result from the phasing-out of fossil fuels and the emergence of new climate-friendly industry.

### **Box 9.1 Climate targets**

Norway is formally obliged to reduce national emissions in the non-quota sector and this will increase the demand for power. For the quota sector, Norway is also obliged, but in collaboration with the EU, so that the reduction in emissions can be taken in other countries if the Norwegian measures are the most expensive. The degree of national emission cuts in the quota-liable sector affects the increase in demand for power here at home. The large European transition also creates a market for new industry with high power use, such as battery cell production and hydrogen production.

In line with the Paris Agreement, Norway has reported a reinforced climate target. The goal was updated in November 2022, and is now to reduce greenhouse gas emissions by at least 55 per cent by 2030, compared to the 1990 level.

For 2050, Norway aims to become a low-emission society. It is specified with a reduction of the order of 90 to 95 per cent of national greenhouse gas emissions, cf. section 4 of the Climate Act.

[Box End]

### **9.3 The use of power increases in the industry**

In all the projections, it is pointed out that power use in the industry will increase. How much consumption in the industry will actually increase depends, among other things, on how strong climate policy will be, how competitive Norway is hosting a new industry, and the extent to which the development in the power sector facilitates increased use of power. Here we discuss developments in new and existing industries.

#### **9.3.1 New industry**

Norway has good prerequisites for establishing a new industry in addition to the existing power-intensive industry. The projections in the long-term energy market analyzes point to an increasing power requirement from industry and other industries with high power use. At the same time, many of the industrial plans are immature and uncertain, partly due to uncertainty about online connection. This makes it challenging to estimate the size of the increase in industry power requirements.

Process21 has made a consumption estimate for 2050, which shows an increase of around 82 TWh of power use compared to 2020 (Process21, 2020). About 65 TWh of the increase takes place in industry and in the petroleum sector. They estimate an increase in the use of power of approx. 8.5 TWh in existing industry and new facilities in existing industries. They calculate 15 TWh for hydrogen for process industry purposes, and approx. 1.3 TWh to CCS. In addition, they expect a growth of 9 TWh for data centers, 6 TWh for battery factories and 10 TWh to synthetic fuel. Electrification of shelf and associated land facilities will draw approx. 15 TWh.

In 2021, NHO and LO published their energy policy platform, pointing out possible annual power use of 170-190 TWh in 2030, given their ambitions (NHO and LO, 2022). This is an increase of 35-55 TWh. They assume that Norway will reach its climate goals, and that Norway succeeds in ambitious industrial investment in line with NHO's roadmap for the future business community, "Green Electrical Value chains", Process21 and Konkraft's road map.

In the ambitions of energy policy platform, more requirements for power distribute 8-12 TWh to battery factories, 10-15 TWh to green hydrogen/ammonia, 5 TWh for further development of the process industry and 11-13 TWh to electrifying parts of the oil and gas business. They describe that 7-10 TWh can also be triggered for green transition of transport and 7-11 TWh for the establishment of data centers. At the same time, they consider that energy efficiency could free up to 10 TWh by 2030. They also point to the need for rapid development of energy infrastructure.

Establishment and location of new industrial activity is influenced by global conditions, international and national policy formulation, regulation and tool use. There are great gaps in the estimates of the industry's future power use. In order to provide a more complementary basis for assessing what affects the development of the power requirement in the industry, Oslo Economics and SINTEF, on behalf of the Energy Commission, have investigated important decision factors for the industry.

In the study, Oslo Economics and SINTEF point to battery cell production, hydrogen and ammonia production, data centers, carbon capture and storage (CCS) and land-based farming as the most relevant new industries. Their investigation is based, among other things, on interviews with industry players (Oslo Economics, 2022). Figure 9.4 shows which elements representatives of these new industries are given relevant decision-making factors. Dark fields indicate that a factor is particularly important for it to be appropriate to establish a specific type of industry in Norway, the more shaded fields the more important is the factor. Bright fields indicate that the factor is less important, and white fields indicate that the factor is of little significance.

	Battericelle produksjon	Grønt hydrogen	Blått hydrogen	Datasentre	Karbonfangst og -lagring	Landbasert oppdrett
<b>Egenskaper ved kraften</b>						
Nettilknytning	■	■	■	■	■	■
Kraftpris og nettariff	▒	■	▒	▒	▒	■
Fornybar kraft	■	■	■	▒	■	▒
Leveringssikkerhet strøm	■	▒	▒	■	▒	■
<b>Tilgang på og kostnader ved innsatsfaktorer</b>						
Arbeidskraftintensivt	■	▒	▒	▒	▒	▒
Kompetanse hos tilgjengelig arbeidskraft	■	▒	▒	▒	■	▒
Lønnskostnader	▒	▒	▒	▒	▒	▒
Nærhet til råvarer/råvarepris	▒	▒	■	▒	▒	■
Ferskvanns- og/eller saltvannstilgang	▒	■	▒	▒	▒	■
Tilgang på store arealer	■	▒	▒	■	▒	■
<b>Andre vesentlige forhold</b>						
Havn eller annen transportinfrastruktur	▒	▒	▒	▒	■	▒
Kunnskapsmiljøer og teknologiutvikling	▒	▒	▒	▒	▒	■
Støtteordninger/annen tilrettelegging	■	■	■	▒	▒	▒
Markedsadgang EU	■	▒	▒	▒	▒	▒

Figure 9.4 Important factors for establishing industry

Oslo Economics and Sintef (2022).

Online connection appears to be the most important factor for industry players to consider it relevant to establish themselves in Norway. Most also point out that the power must be renewable, especially in battery cell production, hydrogen production and carbon capture and storage.

Data center players, battery cell manufacturers and fish breeders have pointed to good supply security for electricity as a particularly important factor. These are processes that have little tolerance for interruption. Hydrogen producers, in turn, have greater tolerance for interruptions, and can position themselves as a flexible resource in the power system. Co - location with players in other parts of the value chain can be important. The areas must also be proximity to the necessary infrastructure, such as port, airport and rail. Access to port/transport infrastructure is especially important for carbon capture and storage. Infrastructure will generally be important for industry that produces goods for sale on the world market.

Market access to the EU is particularly important for battery cell production, as in the EU in recent years there has been a major commitment to batteries. The EU has identified batteries as a strategic value chain, with a desire to break the EU's dependence on countries outside the EU.

Competence was particularly highlighted as important for battery cell production and carbon capture and storage. Available labor was most important for battery cell production. Almost everyone was concerned with support schemes and framework conditions, especially battery cell production and hydrogen, which are at an early stage of development. Technology development and knowledge environments were important for farming.

Norway can be attractive for the establishment of a new power-intensive industry, provided that network connection and secure delivery of renewable power will be facilitated. Norway already has some expertise in professional environments and established industry, and a highly educated workforce with expertise that can have transfer value to new industrial activities.

The coast of Norway can provide access to effective transport opportunities, and access to areas that may be suitable for industrial establishments. In addition, establishment in Norway can provide proximity to and access to the European market.

### **9.3.2 Existing industry**

The end use of electricity in the industry has varied between 41 and 52 TWh since the 1990s. Electrification in the existing industry will increase the use of power. Fossil energy products that go to combustion can often be replaced with electricity, while the use of fossil energy products such as raw material in processes can be less replaced by direct use of electricity. Here hydrogen can be an alternative, which will indirectly contribute to increased use of power if it is produced through electrolysis.

Electrification is an important, but not the only factor that affects the use of power in the industry. Large parts of the industry compete in international markets and are influenced by business cycles. After the financial crisis in 2008, the demand for goods fell, and the use of power dropped by 9 TWh from one year to another. Demand gradually rose and reached the same level in 2021 as before the financial crisis, 49.3 TWh.

The price of the final products is of great importance to the activity and varies considerably over time. The producer price index for the industry overall increased by 23 per cent from September 2021 to September 2022 and in this way compensates to some extent for increased energy prices. Exchange rates also affect the Norwegian export industry. A strong krone gives poorer competitiveness than a weak krone.

Commodity costs are important for the industry, but raw materials are often traded in global markets, so competitors meet the same price. For the industry, power is an input factor in production. Power prices vary between countries and mean a lot to the competitiveness of the power-intensive industry. Increased power prices do not have any significance for the industry's competitiveness if competitors receive the same cost increase. However, the market can find less power-intensive, and cheaper, products so that the competitiveness of the existing industry is indirectly affected. The high electricity prices will also contribute to a higher energy efficiency than used in the projections of 2021. The power support scheme for the business community adopted by the Storting in September 2022 also has conditions to implement energy efficiency measures.

In an analysis performed on behalf of the Ministry of Petroleum and Energy, DNV and Vista analysis have looked at the effects of increased prices for business (DNV and Vista Analysis, 2022). They find that the use of electricity and activity has dropped, but that there are large differences between the industries. For some industries, electricity costs make up a small part of the budget. Power intensive industry often has fixed price contracts and has therefore been less directly exposed to price increases. The largest decline in power use due to increased electricity prices occurred in the industries agriculture and forestry, tourism, knowledge-intensive services, water and drainage, fishing, catch and aquaculture.

DNV/Vista analysis finds that the calculated changes in activity level are less than the changes in power consumption. For many industries, increased electricity prices will stimulate energy efficiency or transition to other energy alternatives. The results indicate that



the strongest energy efficiency effect is the strongest. In existing power -intensive industry, the possibilities of switching energy carriers are limited.

In general, the political framework conditions are important for the industry. Norway has a stable and good political regime that makes the country attractive to industry. Highly trained personnel generally have low wages compared to other countries. At the same time, the minimum wage is higher than is usual in competitors. The electricity tax is low. By 2022, the ordinary electricity tax rate is NOK 8.91 per kWh from 1 January to 31 March, and 15.41 øre per kWh from April 1 to December 31. The industry has a reduced rate of 0.546 øre per kWh.

The ability to renew and efficiency is important in order to compete over time. We have good research and development environments that work closely with the industry on both product development and efficiency. Energy efficiency can limit the use of power, both through the efficiency of the processes, and through increased utilization of surplus heat, see Chapter 9.4. Existing industry can also change activity or start new activity. Several large industrial companies have rights to some increased power output in the network within existing agreements with the grid company. They may have an advantage compared to new industrial companies that need to compete for scarce resources in the web. If production is expanded, it can increase power consumption.

#### **9.4 Potential for energy efficiency**

Power use in Norway is increasing. With energy efficiency, we can maintain comfort in our buildings and production in industry and at the same time reduce energy consumption. With energy efficiency, we can dampen the increase in the total use of power, and strengthen both the power balance and the power balance. In this way, energy efficiency will also limit the need for increased power development with associated nature interventions.

Both households, service sector and industry have the opportunity to streamline energy use and at the same time contribute with flexibility in the power system. There is a great theoretical potential for energy efficiency, but the profitable potential is less.

#### **Box 9.2 Profitable Energy Efficiency**

Several different concepts are used for reduced energy consumption. In energy efficiency, both comfort and activity level can be maintained, one user only less energy to achieve the same result. Energy efficiency can be profitable for the end user, but it can also be unprofitable. When saving energy, it may be appropriate to reduce comfort and production.

Energy Economics (ENØK) is another variant of energy efficiency, and means that we put the same financial goals on measures to save energy consumption, as on measures to increase the supply (Director General of NVE, 1983). If the energy prices represent all the costs of the energy system, they can be used as a basis for assessing the socio -economically profitable single -potential.

There may be various reasons for adding energy efficiency to higher socio -economic value than represented in market prices. Power generation provides nature interventions, ie environmental costs, which are not explicitly reflected in the costs of power development. The funding of the grid is partly a splice layer where scarcity of transmission capacity is not fully fully reached as a price signal. The end users are unable to have an overview of the possibilities for, and the profitability of, energy efficiency. The cost of obtaining information represents a market failure.

Development of new energy -efficient technologies, and good market solutions for the spread of technologies, are necessary to promote energy efficiency. In all technology development, there is market failure in the various phases of the innovation chain. Knowledge can be

spread, utilized and further developed without deteriorating it. Companies that invest in new technology and knowledge therefore do not get the whole gain. In addition, in the development of environmental technology, there are some special market expectations. This means that the business community will invest too little in research and development in general, and environmental technology in particular. Reference is made to the Green Tax Commission (NOU 2015: 15, 2015).

At the same time, the end use of electricity in buildings is taxed, some support is provided for energy efficiency measures, there is R&D activity in the area, and we have regulations that promote energy efficiency. However, the tax rate on electricity is far lower than in our neighboring countries and elsewhere in Europe. The industry in Norway has the lowest permissible tax rate on the final use of electricity within the EEA Agreement (EU, 2003).

[Box End]

### 9.4.1 Potential in building

The potential for energy efficiency in the building stock has been described by many actors, for different purposes and with different assumptions.

Figure 9.5 shows how energy consumption is distributed on different purposes in the different building categories. Much of the energy consumption in buildings goes to heat purposes, see section 5.1. All potential studies point to the possibilities of limiting the heat demand in existing buildings. Some studies also look at other elements, such as measures on cooling, fans and pumps, electric -specific equipment and lighting. The potential for reduced energy consumption through the use of heat pumps is also illuminated in some of the analyzes.

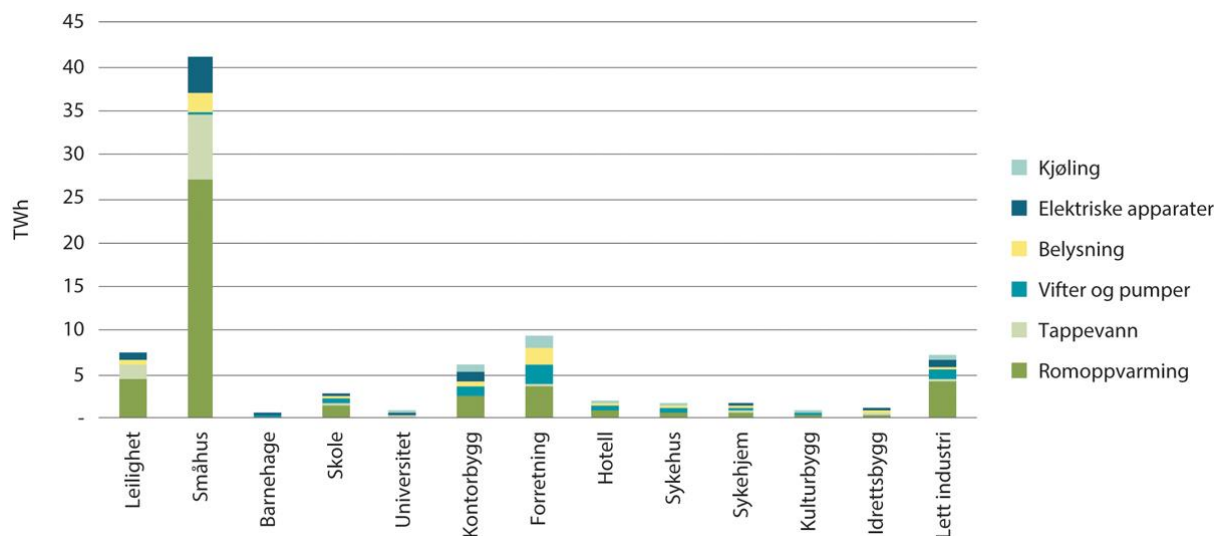


Figure 9.5 Energy requirements in 2019 distributed over energy purposes in the various building categories, TWh1

1 holiday homes are not covered.

NVE (2022)

There are limited statistics for analyzes of the energy efficiency potential in buildings, and part of the data base is estimated. The calculation methods vary, but all studies are based on a Bottom UP approach. Some give a static picture of what is achievable if all buildings are lifted to a specific standard. Others give an assessment of how quickly such a boost can happen. In the calculations of economic potential, costs, calculation interest rates and price assumptions may be different. The potential calculations made are therefore not comparable.

## **SINTEF and NTNU's calculation of potential in buildings**

SINTEF/NTNU has calculated how much energy efficiency will come in housing and commercial buildings towards 2030 and 2050, given that today's trends with energy measures in buildings in connection with rehabilitations will be continued. The trend means that 20 per cent of buildings that are rehabilitated are energy upgraded and that the rate of renovation is one per cent per year for housing, and 1.5 per cent for commercial buildings. They only look at measures on the building body and assume that buildings are lifted to TEK10 standards when renovated. They assume that further energy upgrading of existing buildings, to TEK17 level or better, is not realistic because it will require a greater extent to rebuild the shape and function of the buildings. Buildings that are demolished are replaced with buildings that are built according to TEK17 standard.

In this basic projection, SINTEF/NTNU finds an energy efficiency of 3.1 TWh from 2015 to 2030, and 7.8 TWh towards 2050. Although there is an energy efficiency, the total energy consumption in buildings increases by 3.4 TWh in 2050, because the total building area increases (Sandberg, 2022).

They have also looked at a scenario where all existing buildings to be rehabilitated to TEK10 standards. They then find an efficiency potential in existing buildings of 5.5 TWh in 2030 and 14.2 TWh in 2050. Half of today's existing buildings have then undergone rehabilitation and energy upgrade in 2050. Lower in 2050 than in 2015. It is assumed here that new buildings follow stricter energy requirements than TEK17.

In a separate scenario, they assume that there will also be 16 TWh extra energy production from increased use of heat pumps. Buildings that are rehabilitated and new buildings receive water-borne heat and geothermal heat pumps, while all other buildings get air for air for air heat pumps. This results in a reduced total energy consumption of 19.5 TWh in 2050, which is 23.5 TWh lower than in their basic projection.

There are several who have pointed to great potential for energy efficiency by using heat pumps to a greater extent. Hearing strategy and counseling have calculated an energy saving potential from heat pumps of 7.5 TWh per year in existing buildings, in addition to the 10 TWh that has already been realized. Such a potential can be realized during a 10-year period (Grini, G. and Oksvold, I., 2019).

On behalf of Enova, SINTEF has made its own potential and barrier study for energy efficiency in commercial buildings (SINTEF, 2020). In this study, they look specifically at the possibilities of developing an energy service market. That is, a third party facilitates energy efficiency in the buildings. They find a technical potential for energy efficiency of 15.9 TWh. SINTEF points out that there are some barriers to getting such an energy service market. The most important barriers are a high financial risk to the suppliers, that building owners want to operate building and construction themselves, and that it is demanding to agree on the distribution of the gain between the building owner/tenant and the building owner/supplier of energy solution. In addition, there is a lack of knowledge about the market and lack of purchasing expertise.

## **NVE's calculation of potential in buildings**

NVE has developed its own model for the building mass's energy state, and made incoming potential calculations. NVE has based the calculations on figures from, among other things, the energy labeling scheme for buildings. They have specified various measures in 13 different building categories, and find great potential in existing buildings through post-insulation of the building body, replacement of doors and windows and improvement of heat recovery and ventilation. NVE has also looked at the introduction of various management

systems, energy follow-up etc. The work has been carried out in collaboration with the Directorate for Building Quality (DIBK).

In addition, NVE has made potential calculations of measures that can be profitable to implement, from the end user's point of view. Here, realism and costs of specific energy efficiency measures in buildings are assessed (Multiconsult, 2021). Costs and energy savings have been calculated for 13 energy efficiency measures in small houses, residential blocks and commercial buildings divided into 4 different building periods and 5 climate zones. Many of the measures have long-lasting effects, are relatively easy to implement, and contribute to better comfort and more flexibility

The possibilities of installing heat pumps and solar energy systems are not covered by the study. The natural replacement to more effective electrical appliances is also not considered.

In this study, NVE assumed that measures with costs below NOK 1/kWh were profitable, which corresponded to a representative electricity cost for the end users at the time the analysis was done. In small houses they found a profitable potential of approx. 3 TWh, given an interest/return requirement of 12 per cent. For housing blocks, the potential is less than 1 TWh, with an interest rate of 9 percent. Commercial buildings have the far greatest potential, with 10 TWh, given an interest rate of 6 per cent. All in all, the potential for profitable energy efficiency is around 13 TWh with these assumptions.

The measures that come out as the cheapest in the study are energy follow-up, night and weekend lowering, post-insulation of wall and attic, lighting control system and energy efficient lighting equipment, and ventilation measures (improvement of fan efficiency, needs management and heat recovery). The high interest rates used in the cost calculations reflect that energy efficiency measures are often not a high priority by the end user. In Figure 9.6, the cost curve for energy efficiency in commercial buildings is reproduced.

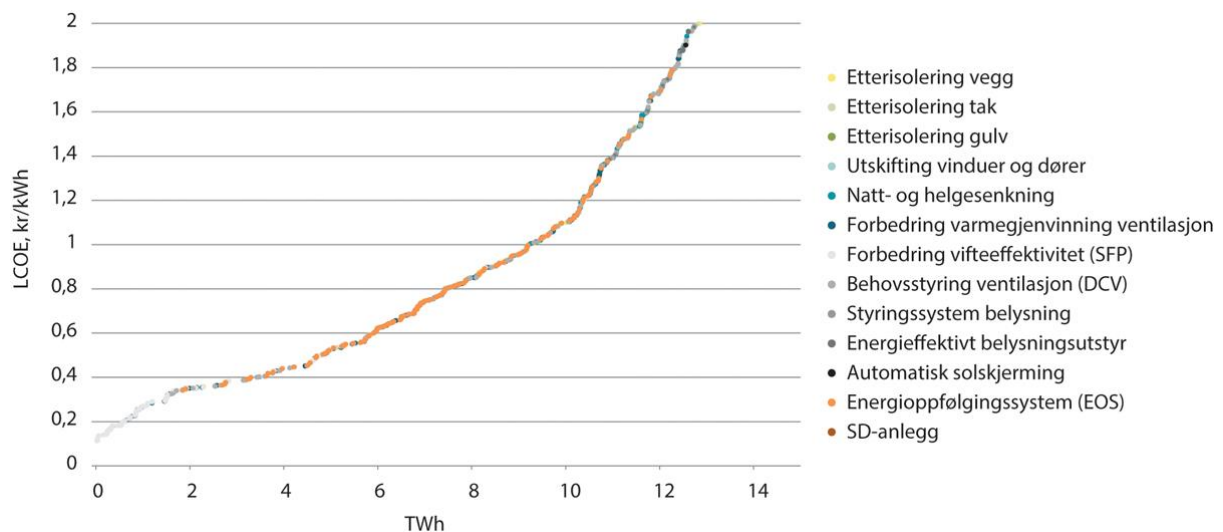


Figure 9.6 Profitability curve for energy efficiency measures in commercial buildings, LCOE, kr/kWh

NVE (2021)

NVE has also calculated the potential at 4 per cent interest for all building groups. The calculations then show a potential of approx. 24 TWh at a cost below 1 kr/kwh.

Box 9.3 Temperature correction of energy consumption in buildings

NVE estimates that room heating accounts for 57 per cent of the energy consumption in the Norwegian building stock. Energy use in buildings is therefore largely affected by the outside temperature. NVE has previously pointed out that energy consumption in the building stock can have an annual variation of as much as +/- 5-6 TWh due to temperature variations. When long-term trends or potentials are to be considered, temperature-corrected energy consumption is used. An example of this is an analysis of the consumption's response to high power prices.

[Box End]

### Energy efficiency in buildings in the projections

In recent years, energy consumption in the building stock has leveled off. In NVE's latest long-term analysis (NVE, 2021), the development of energy consumption in buildings is calculated based on existing instruments. According to NVE's analysis, the total use of electricity in buildings is reduced by 6 TWh towards 2040, compared to temperature-corrected consumption figures for 2021. The power prices that were used in the analyzes are far lower than today's prices.

The expected reduction in energy consumption in buildings comes despite both the population and the building area increasing. This shows that significant energy efficiency is expected in the building stock in the future. NVE estimates that the energy efficiency in Bygg dampens the power consumption by 8 TWh in 2040 compared to what it would have been without efficiency. The analysis shows that the energy efficiency in isolation dampens the average Norwegian power price by 4-5 øre/kWh in 2040. The price effect is strongest in the years of least inflow, in population-tight areas with tight power balance and winter time. Figure 9.7 shows the calculated price range throughout the year in 2040 for different years. The gray dotted lines show calculated maximum and minimal weekly values for the simulated veins in a path where energy efficiency does not occur. The blue dotted lines show maximum and minimal weekly values in a path where energy efficiency occurs. The solid lines show the difference in the average price for the veins, with and without energy efficiency.

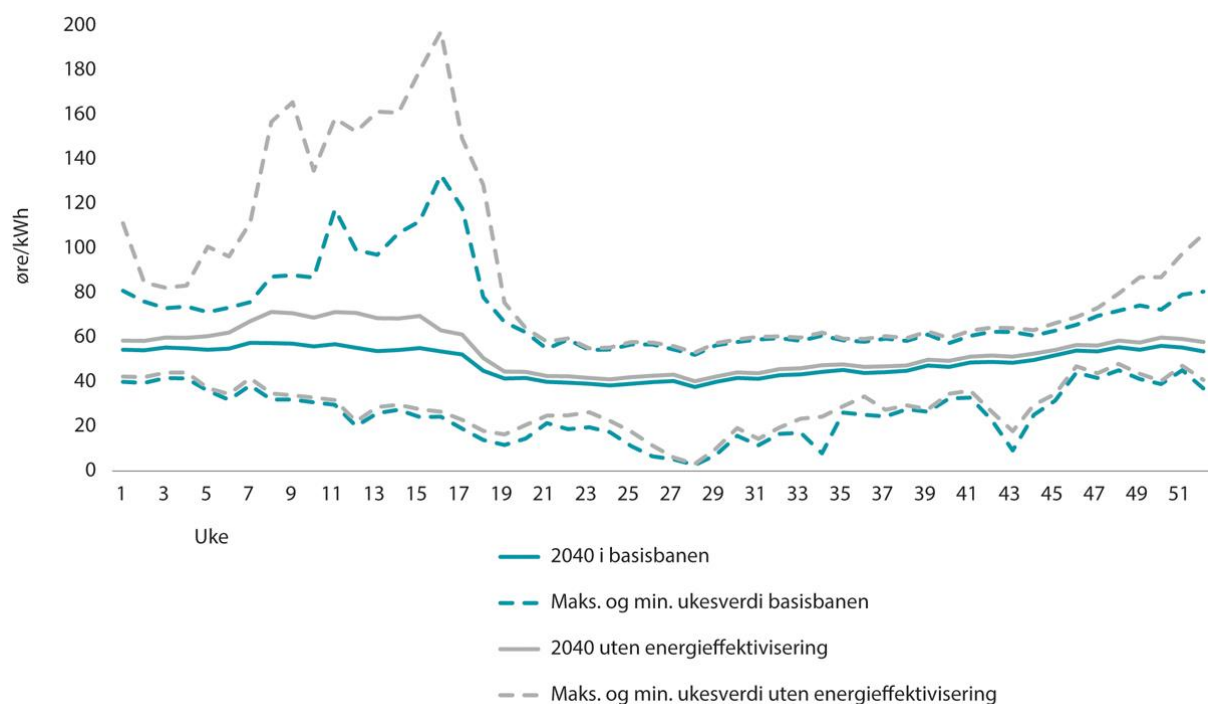


Figure 9.7 Average Norwegian weekly price in 2040 with and without energy efficiency measures. Maximum and minimal weekly value in 30 simulated year in NVE's basic path and in orbit without energy efficiency, ear/kWh

NVE (2021)

#### Box 9.4 Solar power

The potential for utilizing solar energy for power generation is significant, also in Norway. Areas on roofs and walls can be utilized to install solar panels without new nature interventions. With the installation of solar energy on buildings, consumers' need to buy electricity from the market can be significantly reduced, and they can sell electricity at times. The question of solar energy often arises in the context of energy efficiency measures in buildings. However, Solstrøm is considered power generation. Large solar power plants can be built where new areas can be used or they can be linked to buildings. Solstrøm is discussed in more detail in Chapter 10.

[Box End]

Statnett is also expecting falling power use in general supply. NVES and Statnett's analyzes are not done with the aim of finding the potential for energy efficiency, but shows a development in power use with the framework conditions and expectations of power prices that were relevant at the time of analysis.

#### 9.4.2 Potential in industry

The industry can energy efficiency by introducing more efficient processes, or through increased utilization of surplus heat.

The energy cost is a dominant part of the production cost in many of the major industrial companies. Power intensive industry has long worked actively with optimization of processes to streamline energy consumption. The potential for further energy efficiency through process improvements in the power -intensive industry is limited given today's technology, according to the industry itself (Oslo Economics, 2022). Several major industrial companies are working on developing new technology to further streamline their processes, including with a view to reduced power use. At the same time, there is a lot of activity to reduce greenhouse gas emissions from the industry, and several of these measures will involve changed composition of energy use, with increased use of power and less use of fossil energy carriers.

Production processes form surplus heat that is largely lost. It can be in the form of warm air, water, steam or exhaust. The temperature of the excess heat varies from 20 to over 300 degrees. In some cases, the heat can be utilized directly, and in other cases the temperature can be raised with a heat pump so that it becomes useful for specific needs, see illustration in Figure 9.8. If the temperature is above 300 degrees, the excess heat can be used to produce electric power. Several ferrosilium plants in Norway today produce electricity from surplus heat, and in this way recycles about a third of the current they use.

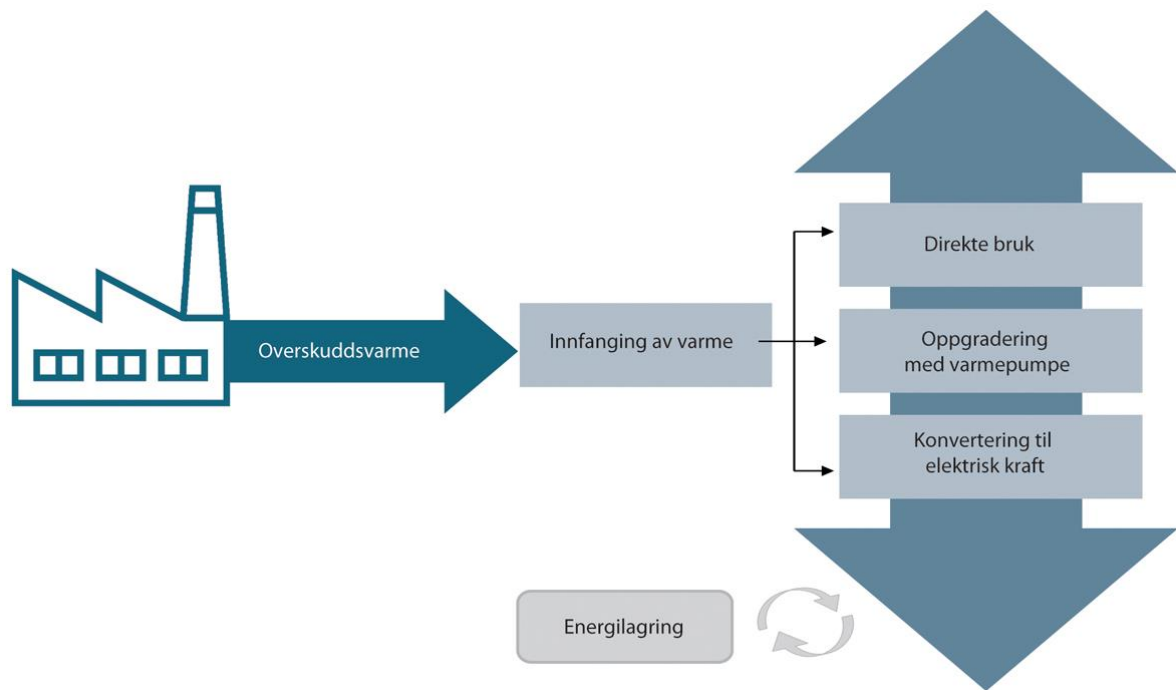


Figure 9.8 Areas of application for excess heat

Oslo Economics and Sintef (2022).

Much of the industry's need for high temperature process heat (100 to 200 ° C) is produced by gas or oil products, and some use electricity. By replacing electric boilers with heat pumps, power use can be reduced by between 60 and 75 per cent. Today, there is heat pump technology that can raise the temperature from, for example, 80 ° C to 120 ° C (Nekså & Røkke, 2019). More heat pump solutions are tested for higher temperatures.

The heat can be utilized internally in industrial activities, in nearby industry with heat demand or in district heating. SINTEF estimates the technical potential for increased utilization of surplus heat from the industry to the order of 20 TWh (Oslo Economics and SINTEF, 2022), half of which are waste heat from the ferro and aluminum industry. Excess heat with temperature between 100 and 250 ° C makes up 6 TWh of this. The estimates are rough.

The biggest barrier to increasing the utilization of surplus heat is the lack of disruptions. If new businesses are established near the existing industry, it will facilitate the utilization of surplus heat.

Green hydrogen production and data center are examples of new activities that form significant amounts of surplus heat, while land -based farming and production of battery cells are examples of activities that require a lot of heat. Co -location of such business can also open to utilize each other's value chains beyond the utilization of surplus heat. For example, horticulture can utilize biological waste from land -based farming. District heating systems can distribute surplus heat from many different companies.

The industry is heterogeneous with many different processes, and energy efficiency measures must be tailored. Therefore, there are no potential studies for energy efficiency in the industry in the same way as for buildings. Tailoring of measures must start with an energy mapping to uncover specific efficiency opportunities. Enova has a guide for energy mapping on its website, primarily aimed at smaller companies. If energy management is also introduced, energy consumption can be reduced by up to 10 per cent (Kristina Haga Hopland, 2016). The

power-intensive businesses have been consistently implemented this type of measure, but there is probably an efficiency potential in minor industrial companies.

Better utilization of the large surplus heat resources requires an interaction between different industrial companies. Highff is a research center that has energy efficiency in industry as the main area, with broad involvement of the industry itself. Often, municipal authorities must also get involved and facilitate industrial plots etc. for specific projects to be realized.

### **9.4.3 Potential in the transport sector**

Energy use in domestic transport is distributed by about 65 per cent to road traffic, 7 per cent to aviation, and about 27 per cent to shipping. There is a large electrification of the transport sector, which is the result of targeted instruments for the transition from fossil energy carriers to electricity. This technology transition in itself involves a reduction in energy consumption to approx. one-third. The energy consumption in the transport sector can thus be reduced, while power use is increasing. This is included in the various projections of power use. Battery electric passenger cars are largely competitive with fossil cars. Battery-electric vehicles in road transport, such as vans and trucks, are expected to be competitive with fossil.

The electrification, and the energy efficiency, of the transport sector has come the longest on passenger cars, buses and ferries, and primarily covers passenger transport needs. The energy consumption of passenger transport is also influenced by how our cities are organized with distances between homes, work, school, trading centers and leisure activities. A good public transport and facilitation for pedestrians and cyclists reduce the need for energy. Between cities, collective solutions are relevant. In scattered areas there are naturally long distances and we get away from individual transport solutions.

The industry is characterized by a large transport requirement for input factors and finished products both nationally and internationally. For trucks, it is uncertain which technology becomes dominant, but the development seems to go against battery-electric engines. It is also uncertain how the development will be for aircraft, shipping and heavy transport on the way. Within shipping, it is likely that what is light and goes short becomes electric, while what is large and will go far will use other zero-emission technologies, such as ammonia and hydrogen. In aviation, it may be appropriate to electrify the short-haul network towards 2040, while long-haul aircraft may be more relevant for synthetic fuel.

Hydrogen, ammonia and synthetic fuel are more energy-intensive than electricity, because it goes with energy for conversion. The efficiency of the production of green hydrogen and ammonia, respectively, is around 72 and 55 per cent respectively. The efficiency will increase if there is deposit for the surplus heat. While battery-electric motor has an efficiency of approx. 95 per cent, corresponding to hydrogen and ammonia about 50 per cent and 35 per cent. However, the use of hydrogen for transport will require less supply of energy than fossil fuel in the internal combustion engine.

The reduction of energy consumption in the transport sector will thus depend on how much can be electrified and which energy products cover the remaining need. The various projections of power use all point out that energy consumption in transport is declining, but that the use of power will increase significantly by 2040 and 2050. The more element it becomes of ammonia and synthetic fuel, the higher the power requirement can be, as power can be used in production. Of these. Although hydrogen, ammonia and synthetic fuel have a lower efficiency than electricity, they can play an important role in phasing out the fossil in the transport sector. There are energy carriers that can be produced during periods when there is plenty of access to cheap power, stored, thus being a source of flexibility. There are also energy carriers that may have an impact on industrial development.



### Box 9.5 indicators of energy efficiency

Different indicators are used to measure energy efficiency, and they have different advantages and disadvantages. Such indicators are used both to set goals of energy efficiency and set requirements.

Figure 9.9 shows the development in energy intensity in mainland Norway from 2000 to 2021. The energy intensity is measured here as net domestic energy use without raw material and energy consumption in the power and water supply and the petroleum sector divided by the gross domestic product (GDP) for mainland Norway.

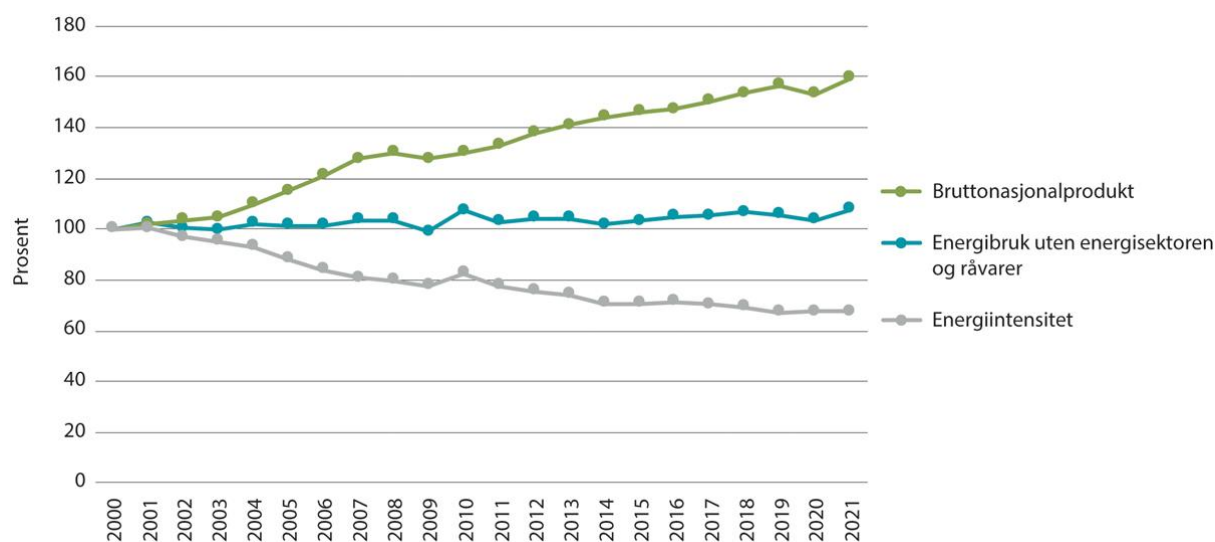


Figure 9.9 Development in energy intensity in Norway 2000–2021 as a percentage  
Statistics Norway (2022) and the Energy Commission.

The economy, measured by gross domestic product, has grown by 60 per cent over the last 21 years, while energy consumption has increased by 8 per cent. This has reduced energy intensity by 32 per cent.

Such an indicator for the entire economy hides several developments in society. An important element is that less energy-intensive industries have stood for much of the growth in the economy. Statistics Norway has made calculations for different periods where the effect of structural changes is separated from other developments using the LMDI method (index for the decomposition of energy consumption in the Norwegian economy). For the period 1990 to 2020, Statistics Norway has found that approx. 55 per cent of the reduction in energy intensity must be explained by factors other than structural change. Statistics Norway interprets this as an improved energy efficiency (Statistics Norway, 2017). Sectoral studies can also be done based on the LMDI method, but it will still be at an overall level. You can see which sectors seem to make the most efficiency. Specific measures, which are often at the center of potential studies, are not revealed.

Norway currently has a target of 30 per cent energy efficiency in 2030 (Ministry of Petroleum and Energy, 2016). The goal is based on energy intensity in mainland Norway, based on 2015. The goal is verifiable with official statistics.

Norway also has a sector target for reduced energy consumption in buildings of 10 TWh by 2030. Statistics on energy consumption are kept in the service sector and households, and here the energy consumption is largely related to the building stock. However, overviews of the actual energy efficiency must be based on uncertain estimates of the development. There

have been discussions about how the goal should be understood and what is to be considered when assessing the goal achievement. In the state budget for 2023 (St.prp

An indicator of energy efficiency can also be linked more to the business itself. For example, the development of energy efficiency in buildings can be measured in specific energy consumption, such as energy consumption per square meter area. In TEK17, energy frames have been set for each building category based on specific energy consumption. For industry, there are several tools where they can compare themselves to similar businesses (benchmarking).

You can also have indicators at the component level. Energy efficiency requirements are set for several products through the Ecodesign Directive (NVE, 2022). For new buildings, among other things, separate requirements are set in TEK for heating (U-values) for windows.

[Box End]

### **9.5 Consumer Flexibility**

Norway has one of the world's most flexible energy systems. The hydropower is adjustable, the consumption side has become flexible after many years of varying prices and we have a robust power grid compared to many other countries. Nevertheless, energy storage and consumer flexibility will also be needed in Norway, as an alternative to grid development and to balance the power system.

Power use has both an energy dimension and a power dimension. The energy dimension is measured in kwh (kilowatt per hour) and is used as a measure of energy consumption and production over a period of time. The power dimension is about how much power is used at the same time and is measured in kw. Kilowatt is used to look at how consumption is distributed over seasons, weeks, days, hours and within the hour. The power peaks occur in the morning (07-11) and in the afternoon (17-19) on the cold winter days and follow the consumption peaks in households and commercial buildings.

We are heading for a tighter power balance in 2030 (NVE, 2022). Previously, power generation and the network were developed to adapt to consumption growth and variations, although there was also some flexibility in consumption. We are now dependent on finding new sources of flexibility in the system, and many of the solutions are found on the consumption side.

Thema and Multiconsult (2022) point to various flexibility measures that can improve the power situation, including measures on the consumption side. Statnett, Elvia, Enova and Norsk District Heating have recently published a report, "The Future is fairly electric" (SystemSmart Energy use, 2022). In this report, the term "system smart energy consumption" is used to denote the role of the consumption page in the restructuring.

In potential studies of energy efficiency, the possibilities of reducing energy consumption are considered. Some energy efficiency measures contribute more to strengthen the effect balance than others, as is also the case for different production technologies, see Chapter 10. Measures on the consumption side can contribute a better power balance in three different ways:

- With measures that can result in a permanent reduction in heat demand in winter, such as efficiency measures on the building shell and alternative heating forms, such as district heating, ground heat pumps and various forms of bioenergy.

□ By switching between the use of electricity and other energy carriers in the heating systems in construction and industry. This is a flexibility that can be stretched over seasons, but it can also be more short-term. Bioenergy, both in gas form and solid form, can be stored. Heat can be stored in the ground, and over shorter periods in thermoses, primarily in connection with larger heating systems.

□ with short-term flexibility, for example by turning off the current for a short while in a water-borne plant, or a well insulated house, without any noticeable temperature drop. Electric car charging and heating of hot water can be moved to periods of day or week when the power output is not at the highest. For electrically powered ferries, charging can be combined with a battery bank.

Traditional energy efficiency measures will in itself contribute to a better balance of power, and many of the measures provide the basis for a more flexible demand page. Flexibility measures include more than efficiency. Table 9.3 summarizes some of the most important sources of consumer flexibility, with examples from industry, building, electric cars and ships.

Table 9.3 Sources of Consumer Flexibility

Type tiltak	Lasttype	Industri	Bygg	Elbil	Skip
<i>Kutte forbruk</i>	<i>Prosesser som kan avbrytes</i>	Stopp i produksjon med reduserte vareleveranser	Slå av lys, TV eller annet	Ta bussen i stedet for elbilen som ikke er ladet	Slå av lys og varme på skipet
<i>Bytte til annen energibærer</i>	<i>Laster med alternative energikilder</i>	Olje-/elkjeler Fjernvarme kan bytte mellom elkjel og andre energikilder	Olje-/elkjeler Strømaggregat Off-grid-løsninger inkl. sol, småskala vind osv.	Hybridbiler	Hybridferge: el og biodrivstoff. Skip skifter til aggregat ombord
<i>Flytte forbruk</i>	<i>Trege laster</i>	Varme/kjøling	Oppvarming, kjøling og ventilasjon	-	-
	<i>Laster med lager</i>	Lager av kvernet tremasse i papirindustri Akkumulatortank i fjernvarme	Varmtvannstanker, varmelager eller batteri	Lade- og tappe batteriet (V2G) – lite tilgjengelig i dag	Batteribank på kaien eller ombord

<i>Laster med overkapasitet</i>	Gartneri – trenger kun lys 20 av 24 timer per døgn	Tidspunkt for bruk av vaske- /oppvaskmaski n kan tilpasses	Står i ro lengre enn det som trengs for å lade, tidspunkt kan tilpasses	Dersom f.eks. en ferge ikke må lade ved alle anløp
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Multiconsult og Thema (2022).

Flexibility in consumption can be triggered in different ways. Manufacturers, consumers and energy stores can adapt consumption as a response to power price and grid rent. This is referred to as implicit flexibility. Implicit flexibility can increase by better facilitating the consumption side to participate in the spot and intraday market, and in the reserve power markets, e.g. through lower bid boundaries and through aggregation of bids. Local flexibility markets as tools in grid operations are also being tested today. There are already examples of aggregator companies that compile flexibility services from several households and/or businesses. In the case of explicit flexibility, the grid companies have control of switch -offs, and may have contracts with individual players for such switching off.

Statutory requirements to offer flexibility to regulated prices may also occur. It can be anything from requirements that are made to connect to the power system to special provisions in connection with strained power situations. Connection on terms is an example of such an agreement, where the customer must be prepared to disconnect/reduce energy consumption in certain situations.

Flexible consumption will be important to meet the impact challenge in Norway (Statnett, 2022), both for grid utilization and market clearance. Statnett has system responsibility in Norway and will ensure that there is enough electricity at all times. It is only a few hours a year that the consumption peaks are very high, and the grid companies have to build the network so that they can meet the demand during these hours. The regulation of the network companies prizes efficiency, so they have incentives to look for opportunities to make the best use of the network.

Statnett and the network companies play an important role in facilitating a market where the flexibility services can be traded. RME will have a role in designing regulations and market designs that facilitate such markets. A separate expert group has made recommendations for the future organization and responsibilities of the power system (RME, 2020). Many studies and demonstration projects are underway to develop end -user flexibility. The establishment of Elhub also provides better opportunities to follow up, among other things, whether the flexibility on the end user side is real.

Many of the flexibility resources are small, and there is a need for automation and aggregation of loads. One of the keys to utilize consumer flexibility is good instrumentation in the system as well, and the costs of necessary equipment have been low. Development has made it easier to collect large amounts of information on the condition of the power grid in real time. This data base can be used to identify the need for, and the availability of, flexibility in the system. In order to utilize consumer flexibility, communication between actors is important. For grid companies, work has been initiated to ensure digital interaction between the grid companies (NVE, 2022).

## 9.6 Barriers to effective and flexible energy use

Although great profitable potential for energy efficiency is calculated, the relevant measures are not always implemented. This may indicate that not all the costs of the measures are reflected in the profitability assessments. The costs that are not captured in the calculations

are often referred to as barriers. Based on insights into such barriers, effective instruments can be designed to reduce barriers.

The decision structure for energy efficiency measures is different from the construction of power plants and transfer networks, which are large individual decisions taken by professional players with specialized knowledge. Decisions to implement energy efficiency measures are taken by many and often small players, most without specialized expertise. The relevant measures are of different kinds. In many cases, measures require greater investigations and tailoring. In many companies, such as industry, housing associations and co-owners, the decision path can be long.

In end users, the financial profitability assessment of the measures is only part of the image when they prioritize their resources. The measures must compete with other measures that are also important, both in the industry and in different types of buildings.

For utilization of surplus heat, companies that are different will find together with activities that are on the side of the core business. There should be access to areas to co-locate businesses, and cooperation with the municipalities is important.

In the event of energy impairment, which means that a very high proportion of family income goes to energy purposes, the opportunities to finance investments in energy efficiency measures may be limited. The average budget rate for electricity (exclusive all public benefits) was 6.3 per cent in the population in December 2021, while for the 10 per cent of households with the lowest income, electricity costs accounted for 12.1 per cent (Statistics Norway, 2022). In addition, the proportion of tenants among housing support recipients is 68 per cent, compared to 15 per cent in the population otherwise.

A barrier to energy efficiency that is often pointed out is that those who are responsible for planning and financing should not use the buildings during the operational phase. The buildings are sold or leased to a third party. Investors therefore lack incentives to prioritize investments that result in reduced energy costs during the operational phase.

Large parts of the economic potential for energy efficiency NVE has identified is linked to the operation of the buildings. Here, owners of commercial buildings point out, among other things, that it is difficult to provide energy services that are complete and that are easy to implement without having to deal with many suppliers (SINTEF, 2020). In other contexts, it is emphasized that installation of water-borne heat is particularly expensive in Norway, and that there are many small craftsman companies with limited opportunities to stay up to date in the energy area. This indicates that the supply side is also not completely ripe in all areas.

## **9.7 The driving forces are strengthened**

The price of electricity is an important factor for end-user decisions on flexibility and energy efficiency. Consumers will see swinging electricity prices and high winter prices, power costs in grid, electricity tax and value added tax. The right price of energy has always been the most central factor in ensuring efficiency in both the production and use of energy.

Traditionally, Norway has had lower electricity prices than neighboring countries, and foreign guests have responded to the fact that we have a different relationship with energy than they are used to. The analysis environments assume that the power price will be between 45 and 55 øre/kWh until 2030 and 2050, which is a higher level than we have seen the previous 30 years (about 30 øre per kWh). And prices will be far higher in winter time than in the summer as production throughout Europe becomes more weather dependent. Both NVE's analysis of response to high prices in the winter of 2021/2022 (NVE, 2022), and Statistics Norway's analysis of where the power support scheme has been (Statistics Norway, 2022),

shows that the use of power decreased in the winter of 2021/2022, compared to the previous year. This indicates that there was a significant change in behavior this winter, and that high prices result in reduced energy consumption in the short term. Experience with high prices could also affect long-term investments in energy efficiency solutions, heating solutions and flexibility.

Measurement of energy consumption is crucial for the end users to assess the benefits of limiting energy consumption. The introduction of advanced measurement and control systems (AMS) was, among other things, a link in facilitating energy efficiency in end users. The potential for utilizing the AMS meters in the work on a more efficient and flexible energy consumption is great.

There are also driving forces on the supply side that can strengthen the pace of the restructuring of the consumption side. Opportunities to automate energy management and the network companies' interest in realizing consumer flexibility will be important. For energy service providers, it will be more profitable to offer management systems and management services, and develop good business models for this. Bioenergy and various alternative heating solutions will be more profitable and it will stimulate this part of the energy industry to promote its solutions.

A driving force that has been strengthened in recent years is the pursuit of a good reputation. We see that building owners want buildings that are environmentally friendly and innovative. When construction of new buildings, many are committed to getting a good energy label. The BREEAM classification is also a system for classifying and highlighting buildings with good environmental and energy properties, and developed by the market participants themselves. Energy-efficient buildings are also increasingly gaining better conditions in the financial markets. The GHG Protocol (Greenhouse Gas Protocol) is a standard for measuring and handling greenhouse gas emissions, and is developed and used by 500 international businesses. Energy use is included in the reporting under the GHG protocol.

Circular economy is becoming important for sustainable development and Norway has developed a national strategy for a green circular economy (the ministries, 2020). Reuse of materials and reparability can affect the energy demand indirectly. Circular economy requires joint regulations of products that are traded internationally, and the EU takes a role here. Utilization of surplus heat is included as part of the circular economy itself.

The European Commission builds up the development with requirements and standards. The taxonomy regulations set specific requirements on what is to be considered sustainable, and will be based on institutions that finance buildings, energy facilities and industrial activities. For the industry, it is important that requirements, including in the energy area, apply to all companies that compete in the internal market.

## **9.8 Today's instruments**

Although measures for energy efficiency and increased flexibility appear to be profitable for consumers, different barriers can mean that they are still not implemented. In a situation where the energy conversion is forced by political processes, it can be defended to use special tools for the consumption side. It's about realizing the energy conversion at a high pace. It is also about consumers and business being less exposed to high prices, especially in winter. The instruments should be directed at the identified barriers.

Measures are arranged differently if new technologies and new market solutions are to be developed than in a case where technologies are more mature.

The Norwegian Boligbyggelags National Association (NBBL) has published an overview of existing instruments aimed at buildings in a note on energy efficiency in Bygg (NBBL, 2022). Both NVE (NVE, 2022) and NBBL distinguish between legal, economic and informative instruments. These instruments can complement each other.

### **9.8.1 Continued room for technology development**

Not all market solutions to realize an effective restructuring are completely in place, and there is room for technology development in many areas. A renewed strategy for energy research, Energi21 has recently been established. Here, further research on technologies is planned, also on the consumption side. Integrated and effective energy systems are pointed out as crucial to success in the green shift, including interaction with end users. Research needs are highlighted in, among other things, energy markets, regulation, energy security, energy use and social acceptance (Energi21, 2022). In the Ministry of Petroleum and Energy's budget for 2023, NOK 993.5 million has been allocated for "Research and technology development for the energy system of the future". In addition, the EU has several initiatives for the development of smart energy systems, energy -efficient buildings, industry, heating and cooling. Support is provided through the Horizon Europe research program, which has its own strategies for each sub -area.

In a phase where technologies and market solutions are to be developed and introduced in the market, the instruments are often aimed at individual projects and individual technologies. In a phase where market solutions and technologies are to be introduced on a larger scale, the instruments can be neutral, that is, with competition on equal terms between different solutions. Competition can be a driver for further innovation and development. The instruments are often directed at the demand side, with legal, economic and educational/informative instruments.

In the energy area, there are already many good technologies for energy efficiency and energy merexibility. Several decades of research and market introduction have allowed us to build energy -efficient buildings, use different types of heat pumps and solar energy, district heating systems have been established in the cities, there are good heat recovery methods, there are energy management systems and battery capacity in electric cars, and there are good energy mapping methods. The challenge is to get the solutions widespread in the market and further reduce costs.

### **9.8.2 Legal means**

With legal instruments, absolute requirements for energy efficiency can be set in products and buildings. Such absolute requirements are most relevant in situations where the technologies are mature, so that the players are able to handle new regulations. When the government announced in 2012 that there would be a ban on the use of mineral oil for heating in 2020, the builders had plenty of time to prepare and the energy industry could prepare to deliver solutions. Before TEK17 was introduced, with strict energy requirements for new buildings, the industry had tested the passive house standard over several years. Before the EU adopts eco -design regulations of new products, there are many years of preparation and dialogue with the industry so that the technology is available when the regulation comes into force. There is also a long period of preparation for energy labeling.

Requirements for measures on existing buildings in the Planning and Building Act (§ 31-2) give the municipalities the opportunity to set requirements for the building owner at the main redevelopment and significant change of existing buildings. In theory, this is a very strong tool, which also hits the times where it is right to think about improving the energy state. According to NVE and DiBK, uncertainty is linked to the practice and enforcement of the

regulations and it should be considered whether, and how, the regulations for existing buildings can be improved (NVE, 2022).

Regulations on energy labeling of buildings were established in 2010 and are under revision. Through this scheme, energy labeling requirements are set for the sale and rental of buildings. The scheme has received criticism from the district heating environment, because it is difficult to achieve a good energy label in buildings that are added to heat from external sources, see Chapter 10.7.3. There is potential to improve the scheme on several points. The grade scale can be adapted so that several different measures make it possible to get a better grade, and in this way are better adapted to existing buildings. The scheme can also premiere reduced power use during high load periods in a better way.

An existing legal tool aimed at the industry is requirements for energy management in connection with the emission permits under the Pollution Control Act. In the CO<sub>2</sub> compensation regulations for 2021-2030, industry that comes under the scheme is required to carry out energy mapping. In 2019, the Ministry of Petroleum and Energy had a hearing of a change in the Energy Act and the Natural Gas Act, which requires energy mapping in large companies. A proposal for regulations was on public consultation in 2021. Large enterprises are defined as companies that mainly conduct economic activity, regardless of company form and organization, and which have an annual energy consumption in Norway of at least 5 GWh in one of the last four years before a Energy mapping must be carried out. The proposal has not yet been submitted to the Storting.

In 2021, the Ministry conducted a consultation of proposals for amendments to the Energy Act on requirements for the implementation of utility cost analyzes for the use of surplus heat from energy-intensive plants. The proposal includes power plants, industrial plants, waste incineration plants, district heating plants, remote cooling systems and energy production plants with over 20 MW supplied heat power or 20 MW supplied electrical power, as well as data centers with over 2 MW of the electrical power. The reason why a lower limit value for data centers is proposed than other plants is that such centers are often expanded step by step. The purpose of the proposal was to help players planning to build or upgrade facilities that generate surplus heat become aware of the possibilities that exist to utilize heat. The proposal has not yet been submitted to the Storting.

The Public Procurement Act indicates some principles that may affect the energy area, although the wording is aimed at reduction in harmful environmental impact, and to promote climate -friendly solutions.

A number of market regulations could affect energy consumption in the future. The introduction of a power element in the transfer tariff is one example of that. The work of facilitating small sources of flexibility can be included in the market is another. The plus customer scheme makes it more profitable to install solar cells.

### **9.8.3 Economic instruments**

There are several financial instruments for energy efficiency and consumer flexibility today. Economic instruments are significantly aimed at greenhouse gas reductions, but energy is often involved in the projects.

Enova's schemes are aimed at demonstration projects and market development. They follow the market closely, survey barriers and develop instruments within their mandate. As of today, support is provided for the following:

- Energy mapping in housing cooperatives and housing companies
- Energy measures in municipal housing



- Heating centers based on renewable energy sources (industry and building)
- District heating infrastructure and waterborne heat in buildings
- Energy and Climate Technology in Industry
- Miscellaneous measures in buildings, such as installation of photovoltaic systems and solar panels, balanced ventilation, fluid-to-water heat pump, power control in homes, smart hot water heaters, comprehensive upgrading of the building body and the heat recovery of gray water.

In a time-limited scheme introduced in the autumn of 2022, companies with at least 3 per cent power intensity can apply for Enova for grants to pay the electricity bill and to invest in energy measures. Companies that carry out energy mapping will be able to cover up to 25 per cent of the electricity price over 70 øre for the months October, November and December 2022, while companies that also choose to invest in single measures will be able to receive up to 45 per cent of the electricity price over 70 øre covered. In addition, support comes up to 50 per cent of the investment cost of energy measures that are not already eligible. There are conditions that companies that receive grants cannot take dividends in 2023. Companies with annual power consumption over 100 GWh fall outside.

The Housing Bank provides loans for extensive upgrading of buildings that reduce energy consumption.

Taxes and fees should basically appear neutral. Fees can be used to highlight the costs of environmental intervention, such as environmentally harmful emissions. The Storting has set up an escalation of the CO2 tax in the non-quota sector to NOK 2000 per tonne in 2030. It stimulates to develop and implement technologies that do not have emissions that are taxed, such as green hydrogen and electric cars. Today's electricity tax has a fiscal justification, but it contributes equally to the energy efficiency becoming more profitable for the end users.

#### **9.8.4 Pedagogical instruments**

Educational instruments can stand alone, or combined with economic or legal instruments. There are many places to go if you want guidance and advice on energy efficiency. Enova, DiBK, the National Antiquarian and some municipalities have information activities. For example, DiBK's website "How to renovate energy -smart" tips on how to raise the comfort of the house and at the same time save energy.

Enova's website on energy management "Enova Knowledge" is a tool for energy mapping and energy management that both commercial builders, the transport sector, the industry and the aquaculture industry can use. Energy mapping is a first step to get an overview of the opportunities for energy efficiency that exist in the business. If the energy mapping is revealed through the energy mapping that are not market-mature, support schemes may be relevant. Energy mapping is compulsory for companies applying for funds under the temporary support scheme.

Enova also keeps a register of energy advisors, and sets competence requirements for these. Report projects and various research activities can also help to raise the competence on the provider side.

Training provides significantly through high school, vocational schools, colleges and universities. This also applies to further education of craftsmen and other professionals.

The various industries even prepare standards, for example in energy management or for energy-efficient buildings (ISO standards).

The EU countries have established their own long-term strategies for rehabilitation of buildings since 2013.

### **9.8.5 New instruments**

Norway is in the process of implementing the Building Energy Directive from 2010. The Energy Efficiency Directive from 2012 is also expected to be incorporated into the EEA Agreement. According to this, a long-term strategy for renovation of the building stock will be created. Changes in the Energy Act with requirements for energy mapping in large companies and investigation of profitability by utilizing waste heat in new industrial activities and data centers have been consulted.

The EU is constantly developing new policies in the energy consumption area. Norway follows the processes, assesses EEA relevance and decides on the various directives specifically.

The EU has a sectoral policy in the energy area, see section 6.2. "Europe's green donor" (European Green Deal). In the EU strategy RepowerEU, proposals for an energy savings of 13 per cent of the end use of energy are submitted by 2030. Within energy efficiency, member states are asked to assess in which areas they can strengthen the use of policy instruments, for example::

- oblige key sectors to energy savings (public buildings, etc.)
- Financial schemes (loans, support, etc.)
- Increase the ambitions in energy saving obligation schemes (white certificates)
- Strengthening results from energy mapping
- Introduce additional minimum standards for energy performance in buildings, including heating systems
- Targeted information campaigns
- Certification of players who can provide free counseling, conduct inspection, etc.
- Assess prices (including progressive tariffs) and tax exemptions on fossil fuels.

The European Commission proposes to order to install solar energy on roof over 250 m<sup>2</sup> by 2027 and all homes by 2029, and has its own strategy for this. Establishment of local energy communities in municipalities is also included in the strategy.

There will also be EU regulations for sector integration, where energy efficiency and consumer flexibility are included as important elements. Sector integration means that different energy carriers - electricity, heat, cold, gas, solid and liquid fuels are integrated with each other and with the end user market.

### **9.9 Organization of work with efficient and flexible energy use**

Energy is used in all sectors in society, and the instruments for energy efficiency and energy flexibility are spread on several ministries. Different ministries make decisions that can affect the basis for storing energy and end-user flexibility, utilization of surplus energy, and for energy efficiency in general. Energy must be an integral part of building regulations, environmental and climate policy, management of the transport sector, land management, consumer legislation and industrial investment. The Ministry of Petroleum and Energy has a responsibility for a secure energy supply, where the development on the energy consumption side will have increasing significance. Crossing considerations may arise in many cases.

It will be more important than ever that a direction will be set for how the energy system will be developed in the future. The policy to ensure efficient and flexible energy consumption must also be specified.

Strengthening the work on efficient and flexible energy consumption requires a good strategy and action plan with the necessary instruments. It must be considered whether the existing instruments and regulations are properly arranged and hit the barriers to restructuring. Several instruments must be established to strengthen the restructuring. A good organization of the work on energy conversion on the consumption side requires a good organizational model. Responsibility and authority in monitoring the goals must be clarified.

Setting goals for efficient and flexible energy consumption may be relevant if it helps to strengthen instruments. It can give the owners of the various instruments a clarity on what is the desired priority in the energy consumption area. The various end users can get a direction on what are robust choices for the future. On the provider side, it will provide greater security to focus on the development of business concepts and technologies. Municipalities will receive clearer signals on how they can help strengthen our common energy system. Network companies receive clearer signal in their commitment to consumer flexibility and in their power system planning.

A single goal can hardly embrace all considerations in energy efficiency and flexibility. For that, the challenge is too composed. There are various challenges related to the development of thermal heating systems, energy -efficient building shells, utilization of surplus heat from industry, hydrogen production and data center, and optimization of the operation of construction and industry. It may be more relevant to set goals in some areas than others.

If targets are set, they must be binding. One must decide whether goals should be angled from the individual end user's point of view or from the national point of view. For example, a target can be set for an energy standard in buildings, which building owners are obliged to reach within a period of time. Such a goal obliges the end users, and if it is formulated as a requirement it will also be a tool. Alternatively, the goal may be overall and oblige the authorities.

If dimensions are to be set, they must also be verifiable. It is more demanding to get good verifiability on the energy consumption side than on the production side, as the official statistics are limited and because there are many more players and units that contribute to the goal achievement. The possibilities for measurement and testing should be taken into account if goals are to be formulated, including the possibilities of establishing new information gathering. Responsibility for testing should be clearly placed and routines should be established for regular follow -up and reporting of the goal achievement.

## **10 Developments in power generation**

In the same way as for the development of energy consumption, there is a large outcome room for the development in production. At the same time, this development is determined more explicitly politically. As long as the costs of new power generation are lower than the expectations of the power price in the future, it becomes decisive how much new production is permitted.

Technology development also provides some uncertainty, but first and foremost in that the future can offer new opportunities. It is certain that there is a lot of new power generation that is either profitable already or that will be there by 2050.

If a license is granted for a project, in today's system there is a business -economic assessment whether or not it should be invested. For a developer, the revenue side must

defend the investment, and it is largely only through the sale of power that the developer gets revenue.

The Energy Commission's mandate asks for assessments of socio -economically profitable power generation. Socio -economic profitability means that the sum of the benefits is greater than the cost of society, both what can be priced and what cannot be priced. The benefits of new power generation must be greater than the injuries and disadvantages. Normally, significant parts of this assessment must be qualitative/discretionary, as in many cases it is not practically possible to economically appreciate or quantify the damage and disadvantages of nature and society when developing renewable energy.

On an overall level, only general assessments of typical environmental effects can be made from different types of power generation. Therefore, a priority between different forms of renewable power generation must be based on typical environmental effects, costs and behavior.

## **10.1 Concession Institute**

In most cases, a license (permission) is required to build, own and operate a power plant. The main purpose of the concession institute is that the authorities can regulate and control power generation so that it develops in a socially rational way and with the least possible negative consequences. A thorough concession process helps to ensure good utilization of resources, reduce negative effects and promote local anchoring and acceptance for the projects. In order to grant a license, the benefits of society must exceed the injuries and disadvantages.

The concession treatment is crucial for what can be realized by new power generation. In addition, it is a prerequisite to have access to utilized resources, areas and power grids.

### **10.1.1 Licensable measures**

For hydropower, a license related to resource utilization that is anchored in the Watercourse Regulation Act and the Water Resources Act is necessary. Large hydropower plants must also have a license under the Waterfall Rights Act. Small power plants are treated under the Water Resources Act and have simpler case management rules than large hydropower plants.

Wind power on land over a certain size and power lines with high voltage must have a license under the Energy Act. For lower voltage levels in the distribution network, the grid companies are given a general area license. This means that it is not necessary to apply for a license for each facility.

Solar power is subject to licensing under the Energy Act if high voltage systems must be established or if the owner of solar power plants wants to establish low voltage lines for neighboring buildings for the sale of power.

District heating systems over a certain size are covered by the Energy Act, and the duty of license is also triggered if the plant supplies external consumers.

The Marine Energy Act and the Marine Energy Regulations provide detailed regulation of the management of the resources at sea, including a description of the process for the concession treatment of renewable energy production outside the baseline. In accordance with the Marine Energy Act, marine areas must be opened by the King in the Cabinet of Ministers before the policyholders can apply for a license to build, own and operate renewable offshore energy production.

Renewable energy production within the baseline is dealt with under the Energy Act, but is covered by the provision on opening in the Marine Energy Act.

It is formally possible to apply for permission to establish nuclear power plants in Norway, but no detailed regulations for commercial nuclear power plants have been developed.

NVE is a decision-making authority for all licensed measures that are dealt with under the Energy Act, with the exception of larger power lines (transmission networks) decided by the King in the Cabinet of Ministers. Measures that are dealt with under the Watercourse Regulation Act, as well as major measures under the Water Resources Act, are decided by the King in the Cabinet of Ministers or by the Storting. Smaller measures that are dealt with under the Water Resources Act are decided by NVE or the municipality. The Ministry of Petroleum and Energy is a decision-making authority under the Marine Energy Act. All licenses are granted on specific conditions that regulate the relationship between the concessionaire and the general interests.

The Ministry of Petroleum and Energy is the appeal body for licensing decisions made by NVE and the municipality, while there is no access to appeal in cases where a license is decided by the King in the Cabinet of Ministers or by the Storting. The Ministry of Petroleum and Energy is a decision-making authority in offshore wind cases, and decisions in such cases can be appealed to the King in the Cabinet of Ministers.

Table 10.1 Licensable measures

Tiltakstype	Spenning eller effekt	Lovverk	Vedtaksmyndighet
Stor vannkraft	>10 MW	Vannressursloven, vassdragsreguleringsloven	Kongen i statsråd/stortinget
Småkraftverk	1-10 MW	Vannressursloven	NVE
Minikraftverk	100 kW-1 MW	Vannressursloven	Kommunen
Mikrokraftverk	>10 kW	Vannressursloven	Kommunen
Vindkraft på land	>1 MW eller mer enn 5 vindturbiner	Energiloven	NVE
Fornybar energiproduksjon innenfor grunnlinjen	-	Energiloven	NVE
Fornybar energiproduksjon utenfor grunnlinjen	-	Havenergiloven	Olje- og energidepartementet
Solkraft	>1 kW	Energiloven	NVE
Kjernekraft		Atomenergiloven	Helse- og omsorgsdepartementet
Fjernvarme	>10 MW	Energiloven	NVE

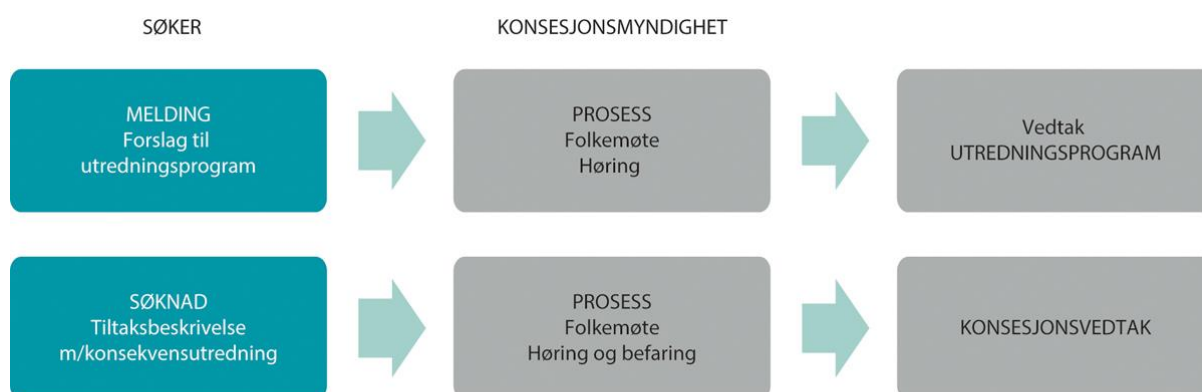
NVE/Energikommisjonen (2022).

### 10.1.2 Case processing

The Public Administration Act provides general rules on the case processing. The Act contains rules on, among other things, case preparation and complaint about individual decisions, and comes in addition to the special rules of procedure in the energy and watercourse legislation. New production and transfer facilities will also be clarified against other relevant laws, such as the Nature Diversity Act, the Cultural Heritage Act, the Pollution Control Act, the Road Act and the Port and Water Act. The case is more extensive for large energy systems than for small plants.

An important purpose of the concession treatment is that the various interests should be heard and assessed, and that conditions are set to safeguard the environment and society considerations. Public hearings in the concession treatment of energy systems are a statutory requirement, and the consultation input constitutes an important part of the knowledge base in the concession assessment. For development plans that affect Sami interests, the Sami Parliament and reindeer grazing districts must be consulted directly in addition to the ordinary consultation.

Measures that require a license under the Energy Act, the Water Resources Act or the Watercourse Regulation Act are required for an impact assessment under the Planning and Building Act. For most major measures, there are also requirements for notification with a proposal for an investigation program. Examples of a case for a reporting measure are shown in Figure 10.1.



Konsesjonsprosessen

Figure 10.1 Simplified presentation of case for a reporting measure. Detailed plan phase and any complaint handling are not shown

NVE (2022) and the Energy Commission.

Solar power plants and renovation and expansion projects do not currently have a requirement for notification. Sea wind power plants are obliged to report under the Marine Energy Act, and a project -specific impact assessment will be prepared to follow the license application.

After a license has been granted for the development of an energy system on land, the concessionaire must create a detailed plan describing how the plant should be built in line with the concession. The plan must be approved by NVE before construction starts, and replaces municipal construction case processing under the Planning and Building Act.

### **10.1.3 Changes in the treatment of wind power on land and at sea**

The licensing treatment of new project applications for onshore wind power plants was temporarily stopped after the national framework for wind power was presented in April 2019. In the period that followed, the Ministry of Petroleum and Energy went through the concession treatment, with the aim of improving and looking at tightening of the practice of the time.

In June 2020, the Solberg government presented Meld. St. 28 (2019–2020) on changes in the concession treatment of wind power on land. In the Storting's treatment of this in December 2020, cf. 101 S (2020–2021), great emphasis was placed on the municipality's role in future treatment of wind power, and it was requested that the planning and construction of wind power plants be incorporated into the Planning and Building Act.

In June 2021, it was opened to resume the final treatment of certain cases, if the host municipality requested it. In April 2022, reports of new wind power projects were opened, if the host municipality consents.

The case processing of messages and applications for new wind turbines will be based on the changes and considerations that result from the wind power report and the Storting's treatment of it, and which can be implemented without legislative and regulatory amendments. A incorporation of wind power into the Planning and Building Act requires a change in law, and this is followed up by the Ministry of Petroleum and Energy and the Ministry of Local Government and District.

In June 2021, the Ministry of Petroleum and Energy opened the consultation of a new supervisor for the area allocation, licensing process and applications for offshore wind power, as well as proposals for amendments to the Marine Energy Act and the Marine Energy Act. A proposal for amendments to the Marine Energy Act is now under consideration in the Storting. NVE has also been tasked with identifying new areas for the development of both bottom -resistant and floating offshore wind.

The Government has decided to announce the first phase of southern North Sea II and Utsira Nord by the end of the first quarter of 2023. In early December 2022, the Ministry of Petroleum and Energy sent out a consultation note with suggestions for pre-qualification criteria, auction model and a possible first-phase support scheme North Sea II, as well as qualitative criteria and support scheme for Utsira Nord. The consultation deadline was January 6, 2023.

The proposal for southern North Sea II means that players who want to participate in the auction for the allocation of land must be pre -qualified, and that a roof is set for the number of applicants who can be pre -qualified. The players are measured by criteria that will help to be done in Norway in Norway in a sustainable way, and provides positive effects on society. Prequalified applicants will then be given the opportunity to participate in an auction. If state aid is needed, the proposal is that this is done through a two -sided differential contract.

For Utsira Nord, five qualitative criteria are proposed that will be assessed together; cost level, contribution to innovation and technology development, ability to execute, sustainability and positive local ripple effects. At a later date, the government will hold a

competition for support among these players. The two relevant models for support are two-way differential contracts, such as on southern North Sea II, or pure investment support.

## **10.2 Costs for the development and value of production**

Norway has a good starting point for restructuring to the low-emission society in the coming years. Our water and wind resources are well suited for renewable power generation, and lay a basis for lower costs in power generation than in most other countries.

The cost of renewable energy production has fallen a lot in recent decades. A combination of targeted political support and market interest has helped to make more renewable technologies competitive. For example, several countries have adopted renewable energy as a political tool, see Chapter 6. In general, different support schemes have stimulated learning, increased competition and cheaper projects. For the industry, increased development has given scale properties, which together with increased competition in the supplier chains have contributed to falling costs.

The natural conditions in Norway, such as solar radiation, rainfall, topography and wind conditions, together with the technological development determine the type of renewable energy that can produce power at the lowest cost. In general, there is wind power on land that can produce new power at the lowest cost per kWh in Norway. In addition, most wind power production in the winter months is when the need is greatest. Hydropower projects can also have low costs. Large-scale solar power has prospects for low enough costs for projects to be profitable in the market. Solar power on a smaller scale, e.g. On buildings, the same trend follows, but the costs here are somewhat higher. Sea wind power is likely to have a significant reduction in the costs of the medium term. Liquid wind turbines have higher costs than bottom-resistant wind power.

NVE follows the development in costs for the relevant forms of power generation. Figure 10.2 NVE's assessment of the cost levels in 2021 and 2030 shows for different forms of power generation. The cost level is stated as LCOE ("Levelized Cost of Energy") - called the energy cost. The energy cost reflects capital costs and operating costs, but not taxes and fees. The cost level is stated per kWh, and does not take into account that the production from the different technologies is to varying degrees is adjustable and therefore has different value in the market.

Figure 10.2 shows that the costs in 2021 are below 50 øre/kWh for land-based wind power, ground-mounted solar power and hydropower. By 2030, NVE expects the costs to fall, so that solar power on large flat roofs will also come lower than 50 øre/kWh. Bottom wind power in Norwegian marine areas will also have costs around 50 øre/kWh in NVE's projection of costs.



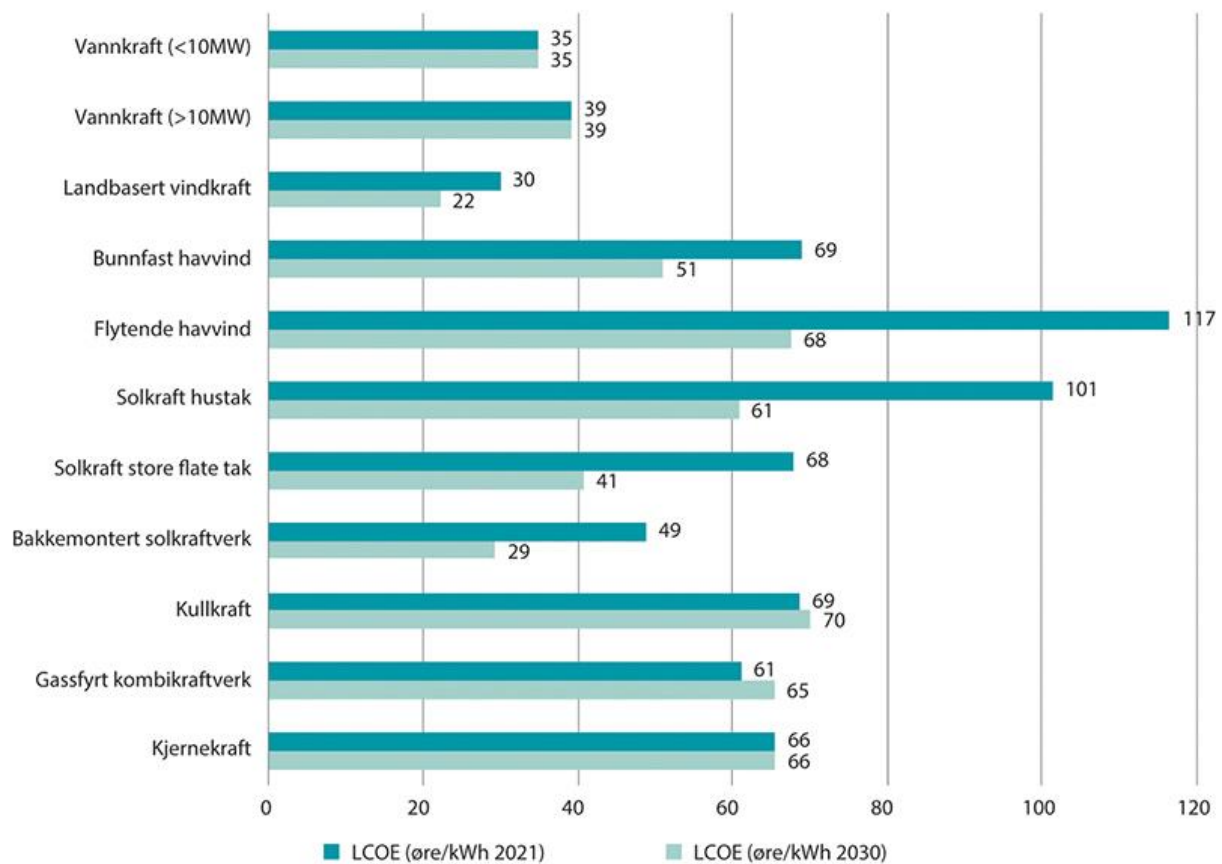


Figure 10.2 Energy cost (LCOE, Ear/KWH) for power generation technologies, in 2021 and in 2030

NVE (2022).

We can expect that the costs of solar and wind power will continue to fall, as increased development of such facilities provides experience and knowledge with associated efficiency gains.

### 10.2.1 The value of power generation varies

It is not just the cost that varies between the different renewable technologies. Also the value of the power, ie the price they achieve for the power of the market, varies. As the power market changes over time, competition will also change.

Adjustable hydropower can produce when prices are high and save the water when prices are low, and can thus achieve a higher payment per produced kWh than hydroelectric power plants that cannot be regulated. This value will increase over time, as much of what comes to substitute for fossil power generation is not adjustable.

The production profiles of the different technologies are different. Solar power and unregulated hydropower produce most in summer, while wind power produces most in winter. Solar power thus produces when prices are normally lower than the average over the year, while wind power produces more when prices are higher. Overall, it provides wind power production higher value than unregulated hydropower and solar power.

In its long-term power market analysis, NVE has assessed the development of prices achieved for five renewable technologies. Figure 10.3 shows that adjustable hydropower will increase in value towards 2040. Of the unregulated renewable technologies, wind power achieves the best prices, and is thus most valuable.

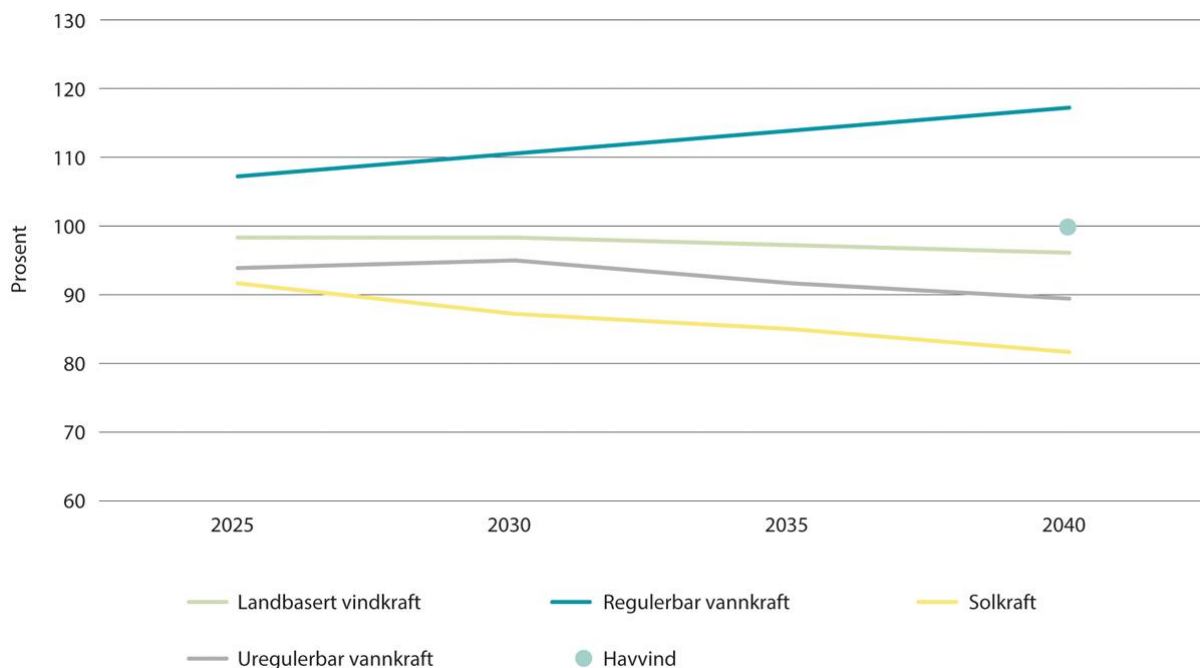


Figure 10.3 The value of power produced from various renewable technologies<sup>1</sup>

<sup>1</sup> The value is calculated as a percentage obtained income compared to the average power price.

NVE (2021) and the Energy Commission.

### 10.2.2 Hydropower

Hydropower is a mature technology with long history. Globally, hydropower is the largest renewable energy technology measured in both performance and production, and the opportunities it provides for storage and flexibility is peculiar.

The hydropower has among the lowest development costs for new production with 35 øre/kWh for large hydropower plants (> 10 MW) and 39 øre/kWh for small hydropower plants (<10 MW). Admittedly, there is variation in costs between the projects. This level has been stable for many years, and NVE believes the cost level will remain so in the years to come (NVE, 2019).

The potential for cost reductions for hydropower technology is less than for other recent technologies, since hydropower has been around for a long time. However, small improvements can be of great value.

### 10.2.3 Wind power on land

Wind power is one of the fastest growing renewable technologies in the world. The average cost of producing wind power fell 56 per cent between 2010 and 2020. In Norway alone, the costs of producing wind power were reduced by close to 40 per cent between 2012 and 2019 (Meld. St. 28 (2019-2020)).

In the last couple of years, however, the wind power industry has been hit by increased prices for raw materials and components, such as steel, which makes it more expensive to produce the turbines. However, the demand for new wind power globally is expected to continue to be large (IEA, 2021).

Wind turbine technology has evolved very rapidly in recent years, and both installed power, total height and length of rotor blades have increased (NVE, 2019). The rotor diameter

globally increased on average from 82 meters in 2010 to 119 meters in 2020, an increase of 46 per cent. Some of the latest wind turbines in Norway have a rotor diameter of 150 meters. Development in advanced control systems also allows the turbines to make better use of the wind and climatic conditions (Irena, 2022).

#### **10.2.4 Wind power at sea**

It is technically more challenging to build wind power by sea than on land, and therefore it costs more. Other foundation solutions, installation methods and operating and maintenance operations are required. At the same time, there may be more to be gained in better wind conditions and the ability to install larger turbines with higher performance at sea than on land, which provides more energy production.

Sea wind power has had a decade in strong growth internationally, and costs have been reduced through both technology development and developments on a larger scale. In the period between 2010 and 2020, the global average of LCOE for offshore wind fell by 48 percent. At the same time, the average project size increased from 136 MW to 301 MW (Irena, 2022).

In most cases, offshore winds have received public support, for example by the public sector covering investigative costs, network costs or through direct subsidies (Meld. St. 28 (2019-2020)).

The cost of bottom-solid wind power, including grid and financing costs is in the range of 50-120 øre/kWh. Towards 2040, the cost is expected to fall to 35–75 øre/kWh (Statnett, 2022) (Wind Europe, 2019).

In Norway, costs will often be higher than further south in Europe, because our marine areas are deep and the distance to land is longer. NVE estimates that a bottom -solid wind turbine built today on southern North Sea II (1,400 MW) will have a cost of 78 øre/kWh, which can fall to between 48 and 68 øre/kWh in 2030.

Wind power can also be installed on liquid foundations. The technology is under development, and the cost level is currently significantly higher than for bottom -resistant wind power. But here too, reduced costs are expected in the long term, from over 120 øre/kWh today to around 50 øre/kWh towards 2050. (Menon, 2022). For Norway, NVE estimates that a floating wind turbine at Utsira Nord (500 MW), built today, will cost 135 øre/kWh, and between 72 and 110 øre/kWh in 2030 (Ministry of Petroleum and Energy, 2021).

#### **10.2.5 Solar power**

Solar power is becoming increasingly effective and more efficient, and is the production technology that is growing the fastest in the world today, measured in performance. In many markets, SOL is already the most competitive renewable energy source (IEA, 2021). The cost of producing large -scale solar power fell on average by 85 per cent in the ten -year period 2010-2020 (Irena, 2021).

The profitability of the solar force depends on the type of installation, geographical location and power price developments. How much energy a solar cell produces depends on solar radiation, air temperature and reflection from snow (NVE, 2022). The costs are lower when solar power is installed on a large scale, as on large roofs, than on small roofs even though the costs also fall here (Irena, 2022).

In Norway, solar power constitutes a small part of our total power generation. Most of the solar power is installed on roofs and is largely linked to the mains (90 percent). With falling

costs and further technology development, NVE expects solar power to compete with both wind and hydropower in 2030, and makes a greater contribution to power generation in Norway than today (NVE, 2021).

The private economic assessment of smaller solar power installations in private houses is significantly different from profitability assessments of ground-mounted solar power on a commercial scale. Solar power on roof means that there is less need to buy power from the grid, so it is most relevant to measure the cost of such solar power up to the cost of buying power from the grid, including fees, grid rent, etc.

### **10.2.6 Nuclear power**

Nuclear power is not a renewable energy source, but is often considered very clean due to the low CO<sub>2</sub> emissions. The great potential of nuclear power means that production, although not renewable, can be called sustainable in isolation.

Based on the experience of recent nuclear power projects in Finland and the United Kingdom, we know that there are long development time and high costs associated with the technology.

The Hinkley Point C power plant in the UK has an agreed price of 92.5 pounds per MWh, or slightly over 100 øre/kWh, which will be indexed from 2012. The project has been under construction since 2016, and is expected to be put into operation in 2027. The power plant. At 3260 MW has an investment cost of approx. NOK 300 billion (EDF, 2022) (BBC, 2022).

Olliluoto 3 was granted permission by the Finnish authorities in 2003, and was scheduled to be put into operation in 2009. The power plant has been postponed a number of times due to large cost overruns and delays as a result of technical problems. As of January 2022, Oolkiluoto 3 is out of service. The cost per kWh is uncertain, but the 1600 MW plant has cost around NOK 100 billion to build, which is more than three times the budgeted investment (Europower, 2022).

At the same time, there is still technology development in nuclear power, and the IEA points to a need for the development of small nuclear power plants and fourth generation nuclear power plants in the 2030s. In its latest long-term forecast for Sweden, the Energy Authority estimates an energy cost for new nuclear power of 60 øre/kWh (the energy authority, 2021). Sweden has experience with nuclear power. For storage, so it will probably be more expensive to build nuclear power in Norway, especially for the first power plants.

The new Swedish government wants a major investment in nuclear power, and will instruct Vattenfall to begin the planning of new nuclear power (energy and climate, 2022). Vattenfall is now making a preliminary study of the possibilities of building small, modular nuclear power plants in Sweden.

Nuclear power plants have high capital costs and relatively lower operating costs, so that the energy cost is greatly affected by the utilization rate, or the use time. The OECD estimates that the energy cost of new nuclear power plants is approx. 60-80 USD/MWH, which is of the same order of magnitude as the energy authority's estimate. Then a power factor of more than 80 per cent is assumed, ie a useful life of more than 7,000 hours (OECD, 2020).

### **10.2.7 Other technologies**

There are several technologies that can produce electricity either renewable or without emissions. It is also possible to build new fossil power plants, or thermal power plants fired with bioenergy. In both cases, CO<sub>2</sub> emissions can be captured and stored. Wave power,

geothermal energy and height wind are also technologies that are often mentioned as promising.

Common to these technologies is that there are no easily available cost figures, because they are not widespread and/or still in a development phase. The Energy Commission has not considered any technologies other than hydropower, wind power, solar power and nuclear power for the period towards 2050. Nevertheless, technology development goes on, and nothing should be excluded.

### **10.3 Nature and environment**

A major challenge in the future will be to develop a lot of renewable power generation and at the same time preserve the natural values and natural goods that we are strongly dependent on. All energy production and associated transfer networks have consequences for the natural environment to a greater or lesser extent and thus also different use and business interests. The impact depends on technology, where facilities are built and how they are built. The following sub -chapters describe typical effects of the various technologies.

#### **10.3.1 Hydropower**

Hydropower production primarily affects the watercourse nature. Many of the country's watercourses are already regulated for power generation or affected by other watercourse measures (ponds, water outlets, flood protection, etc.).

Physical interventions in connection with hydropower development are dam systems, construction roads, power station, piping streets/waterways, power plant drains, mass landfills and power lines. Other influences are hydrological and morphological changes, such as water level variation in magazines, reduced water flow in the river, changed water flow over the year or between seasons and reduced mass transport. Examples of environmental values and interests that may be affected by hydropower development are fish and fishing, natural diversity, landscape, outdoor life, tourism, cultural monuments and wild reindeer.

In fresh water there are 195 endangered species that make up 7.1 per cent of the endangered species in Norway. Hydropower development is one of several factors that help increase the risk that some of these species may die out. River mussels and salmon are examples of species that are in danger of being eradicated. Eel is considered to be severely threatened due to a large decline in population size (Artsdatabanken, 2021). Many eel dies of injuries from hydropower turbines.

Norway has an international obligation to preserve the population of North Atlantic salmon in accordance with the convention for the protection of salmon from 1982. One-third of the total population of North Atlantic salmon is found in Norway. The scheme with national salmon watercourses and salmon fjords includes 52 national salmon watercourses and 29 national salmon fjords where the stocks will be protected from interventions and activities that may have a negative impact. In the national salmon watercourses, there will therefore be a particularly high threshold to allow new hydropower development that can damage the wild salmon.

Many values related to the environment, experience, culture and use are linked to our watercourses. Fosses, water and watercourses are an important part of the experience of Norwegian nature. When the water flow on affected river stretches is reduced, or dry -laid regulatory zones around hydropower magazines occur, the nature experience often also deteriorates. In winter, regulations can lead to unsafe ice and barriers to traffic. Positive aspects of watercourse regulation, for example, contribute to reduced flood hazards and other socially beneficial use such as drainage of water for irrigation.

Renovation and expansion projects (O/U) may involve modernizing or automating the power plant as it approaches life expectancy (upgrading), or more extensive rebuilding to utilize more water or increase fall height (expansion). Renovation generally has few environmental effects. Expansions often cause new nature interventions, but not in all cases.

Pump power plants are assumed to have relatively small environmental consequences if buildings that utilize magazines in connection with existing power plants and infrastructure such as roads and networks. 24-hour regulation, which causes frequent water level changes, can potentially lead to increased erosion and impact on fish stocks and nutritional animals, especially where the power plant has an outlet in the river. Pumping water from a magazine to a high-lying magazine in the same watercourse or between two magazines from different precipitation fields may be at risk of transferring alien species. Since pumping power is currently not widespread in Norway, there are relatively few experiences about the environmental effects of pump power plants.

Small hydropower plants are often built in steep rivers and streams where it is possible to utilize high fall height. The resource mapping for small power plants carried out by NVE shows that many of the suitable sites for such power plants are concentrated in coastal and fjord areas, especially in Western Norway, areas that are rainy and have steep terrain. This indicates that specific nature and landscape types, such as fjord landscapes, may be more exposed to influence from small power than other areas. Pelvic cubes and waterfall zones are examples of habitat types that may be particularly affected by small power development. Small power plants can also affect fish populations and breeding sites for waterfalls that are often located in smaller rivers and streams. The area interventions in connection with small power plants are dominated by road construction and route for pipe street.

### **10.3.2 Wind power on land**

Wind turbines on land, with turbines, roads and installations, require large areas. Wind power is a type of development where the interventions are relatively similar from project to project. This means that it is both possible and meaningful to specify some standard sizes for land use. The area in which the wind power plant will be placed with roads, installations and wind turbines is called the plan area. In addition to the plan area, the surrounding area (the neighborhood of the plant) is also affected. According to NVE (2022), typical values for the area efficiency of wind power when it comes to directly affected area (plan area) are 35 km<sup>2</sup>/TWh. The type number for the direct procedure, including the roads, is 1.6 km<sup>2</sup>/TWh. A development with larger turbines indicates an improvement in area efficiency in recent years. This effect is limited, since the roads make up in the order of 80 per cent of the procedure.

The height of the turbines and location in exposed places in the terrain allows wind turbines to be visible over large distances, and often have a dominant effect in the landscape. Outside the immediate area, the visual effect of the wind turbine is the most prominent effect. In the planning and surrounding area, noise, shadow throwing and risk of ice cream are often central effects. For the sake of aviation safety, light marking of wind power plants is required. Lighting can be experienced as light pollution.

The general picture from licensed wind power projects in Norway when it comes to environmental impacts shows major differences between the sites. Wind power development can lead to loss or fragmentation of habitat type deposits. Birds and species such as reindeer and bats can be exposed to wind power development. Many important habitats for these species are already under strong pressure from several influencing factors. Collisions, loss of habitats and displacement due to disorders are relevant consequences for birds of wind power

developments. Treaty birds often follow specific migratory routes and autumn, and can be affected if wind turbines are placed in the migratory routes.

Reindeer husbandry and wind power are potentially conflicting. Both Swedish and Norwegian studies conclude with a negative impact from wind turbines on the land use of the domestic reindeer. Reindeer husbandry is an area -demanding industry, and about 40 per cent of the Norwegian land area is currently reindeer husbandry. Often reindeer husbandry and wind turbines compete for the same high -lying areas. There are good wind conditions for wind power, but also good pasture and ventilation areas for reindeer husbandry. Loss of grazing areas, stress and behavioral changes in reindeer are possible consequences when developing wind turbines (NVE, 2022).

Article 27 of the UN Convention on Civil and Political Rights (ICCPR) sets limits on the state's access to intervene in minority's cultural practice. The provision must be seen in the context of Section 108 of the Constitution, which requires the state to facilitate the conditions for the Sami people group to secure and develop their language, culture and its social life. In the Fosen judgment (HR-2021-1975-S), the Supreme Court concluded that the wind power development on Storheia and Roan at Fosen in Trøndelag violated the reindeer owners in the affected reindeer grazing district rights under Article 27 of the UN Convention. In the judgment, it was emphasized that the reindeer owners at Fosen operated reindeer husbandry with small margins, that the Southern Sami culture was particularly vulnerable, that other development options could have been chosen in the area that were less intrusive for reindeer husbandry and that no satisfactory mitigating measures were , 2021). The judgment shows that, when establishing wind power plants and other interventions in areas of importance for reindeer husbandry, the Sami minority's cultural practice must be taken into account. The interventions allowed must be assessed specifically in each case.

The wording in Article 27 basically does not open the states to trade in the rights of indigenous peoples and other legitimate purposes. The judgment indicates that this may be different if different fundamental rights are against each other. However, the right to the environment may be relevant in such a context, but in the Fosen case no collision had been detected between fundamental rights.

An overall knowledge base on the effects of land on land has recently been prepared by NVE on behalf of the Ministry of Petroleum and Energy and in collaboration with the Environment Directorate and several other state agencies. The work is a follow -up of Meld. St. 28 (2019–2020) on changes in the license process for land on land, and has been based on existing knowledge of effects, which has now been updated with recent research, relevant literature and the authorities' experiences. The goal is for residents, developers and the Norwegian authorities to have a common basis for assessments of wind power projects. An assessment has also been made of new principles related to pre- and post-surveys in wind power cases. Present and post-surveys are an important tool for increasing the knowledge of the effects of wind power and the effect of mitigation measures. The work shows that there is still a great need for more general knowledge about environmental and social effects of wind turbines. NVE recommends investigating which financing models can be established to conduct larger studies and research projects in this field. In connection with the follow -up of the message, NVE will also prepare an updated knowledge base on wind power and Sami reindeer husbandry and other outbound use. This work is awaiting preliminary Ministry of Petroleum and Energy's follow-up to the Fosen judgment.

### **10.3.3 Wind power at sea**

Sea wind power comprises bottom -resistant and floating wind turbines. Today's knowledge of conflicts and environmental effects of offshore wind exists primarily for bottom -solid installations in sea areas shallower than 70 meters, while one has little knowledge of the effects of floating plants on deeper water. However, there is some useful knowledge of the biology and interests that exist in Norwegian coastal and offshore areas that may be affected by offshore wind facilities. Management plans have been developed for all Norwegian marine areas where, among other things, particularly valuable and vulnerable areas (SVO) have been identified. The management plans are updated and revised every four years.

In additional notification to Meld. St. 36 (2020–2021) Energy for work - long -term value creation from Norwegian energy resources, the Storting adopted: “The Storting asks the government to ensure good environmental knowledge for all parts of the sea environment in areas that are, and can become, relevant for Norwegian offshore wind. Summary and mapping will start in 2022, and the results will be used as the basis for the announcement of areas as well as for nature and environmental requirements for development and operation. ” In an input to the state budget for 2023, Norwea, together with WWF, suggested that NOK 50 million should be set aside for a comprehensive offshore natural mapping.

Many of our sea areas are important traits and pastures for seabirds. The coastlines act as guide lines for migratory birds. There are many studies on how a single offshore wind facility can affect birds, mainly from bottom -resistant facilities in the North Sea. Of greater importance is the lack of studies and studies that look at the sum effects of several wind turbines in a given area, or along the migratory routes for birds and bats.

When it comes to the marine ecosystem, the Institute of Marine Research in a report has summarized the available knowledge of potential effects of offshore wind (De Jong, et al., 2020). Today's knowledge indicates that marine species can be affected in several ways, in the form of changing bottom habitat, low -frequency noise, electromagnetism from power cables, shadows and change of current and surface winds, while wind turbines add to wind turbines in the sea structures that can be developed into artificial foxes, or function as a foothold for alien species. Studies suggest that many fish species are found in larger quantities in wind turbines than in the surrounding sea areas. It is uncertain whether it is because the fish collects around the foundations or the stock has in total greater. It is somewhat uncertain whether floating offshore winds could have effects other than bottom -resistant offshore wind. The Institute of Marine Research discourages wind power development in areas that are especially important for some marine species, such as spawning areas and migration routes for relevant fish stocks and grazing and throwing areas for some marine mammals. In addition, wind power development is not recommended in particularly vulnerable or valuable areas. The Institute of Marine Research recommends that more knowledge be obtained about the possible effects of offshore wind to improve the knowledge base.

Ten years ago, NVE performed a strategic impact assessment on offshore wind (NVE, 2012). The study covered 15 areas along large parts of the Norwegian coast, both coastal and far offshore. The study showed that there were land use interests in all the investigation areas and that the establishment of wind power plants would have consequences for environmental, business and social interests. The study covered seabirds, fish, marine mammals, bottom communities, petroleum, shipping, fishing, landscape and outdoor life, cultural monuments and cultural environment, tourism, the Armed Forces' interests and aviation. The results of the investigation indicate that location choices for sea power at sea, in the same way as for land -based E plant, will have a decisive impact on the scope of the consequence and the interests that are affected.



### **10.3.4 large -scale solar power**

Large -scale ground -mounted solar power plants require large areas. In the Municipality of Stor-Elvdal, a large-scale plant (Furuseth solar power plant) has recently been granted which will require an area of approximately 175 acres (NVE, u.d.). The solar power plant in Stor-Elvdal will be 7 MW with an annual production of 6.4 GWh.

In Norway, we do not have experience with such large solar power plants, and we therefore have little knowledge of the environmental effects of the facilities. Furuseth solar power plants will be useful for gaining experience from the construction and operation of this type of solar power plants. In the Norwegian context, this power plant will in practice be considered a pilot plant.

It may be appropriate to place ground -mounted solar power plants on areas already affected, for example in industrial areas and old landfills, etc. The location of facilities in such areas must be assumed to result in relatively small environmental effects.

Solar power plants in combination with existing agricultural areas and floating solar power plants may also be relevant. The possibilities of establishing solar power plants on areas that are changed from outfield to inland in typical Norwegian forest terrain are under investigation, and it must be expected that there will be licensed applications at such facilities. The environmental consequences and conflicts of interest are probably greater when new areas are to be used than when using areas that have already been affected.

Building and infrastructure-integrated solar power does not normally result in nature interventions and must be assumed to have relatively small environmental effects. However, solar systems can affect the aesthetics and appearance of the building. Installation of solar cells on canopies or facades is subject to application under the Planning and Building Act. For buildings protected by the Cultural Heritage Act, an exemption must be applied for to the county council.

### **10.3.5 Power lines**

Power lines and transformer stations, like other area intervention landscape, outdoor life and natural diversity. Air lines with associated masts are visible in the landscape and can give noise, especially in humid weather. Around all electrical systems in operation, low - frequency electromagnetic fields occur. Guidelines and limit values for exposure to electrical current are shown in the radiation protection regulations.

Air lines can cause collision risk for birds. Larger birds such as hubro and eagles can also die by bumping when the wings come into contact with several phase lines or with a phase line and the mast at the same time. The risk of bird death will vary depending on which routes are chosen and how the plants are designed.

Power lines can act as barriers to wild reindeer and cause grazing areas to be lost or the wild reindeer being divided into several smaller strains. This seems to be especially true if several parallel power lines are placed so that they cross the floors or cut off areas on the outskirts of the pasture area (the Research Council of Norway, 2002).

Soil cables are an alternative to overhead lines. The current guidelines for the use of cable in the power grid are shown in Meld. St. 14 (2011–2012) We are building Norway - on the development of the mains. The main feature of the guidelines is that the use of cable should be high in the distribution network (up to and including 22 kv), but gradually more restrictive with increasing voltage level. The environmental effects of soil cables will depend, among other things, on the type of vegetation where the cable runs and whether there is a need to blast cable route through the mountains.

### 10.3.6 Summary

All energy production will have consequences for the natural environment and user interests to a greater or lesser extent. The effects depend on production technology, location and design. Hydropower must be located where water resources are found, while wind power and especially solar power do not depend on local resources to the same degree, and therefore in principle can be placed in areas where the environmental effects become as few as possible. However, both wind power and large -scale solar power are very area -intensive, which in itself can give rise to conflicts. Globally, changed land use largely contributes to the loss of natural diversity.

The various production technologies affect partly different environmental values and user interests, but there are also many coincidental effects. The review for the individual technologies shows that there are some typical influences that often go back. This is tried to illustrate in Table 10.2 which provides a summary overview of the environmental values and user interests that are experienced in experience.

Table 10.2 Overview of various production technologies and typical influences

Tiltakstype	Miljøverdier – typiske påvirkninger	Brukerinteresser – typiske påvirkninger
Vannkraft	<ul style="list-style-type: none"><li>• Fisk</li><li>• Fugl</li><li>• Naturtyper</li><li>• Landskap</li><li>• Villrein</li><li>• Kulturmiljø</li></ul>	<ul style="list-style-type: none"><li>• Fiske</li><li>• Friluftsliv</li><li>• Reiseliv</li><li>• Reindrift</li></ul>
Vindkraft på land	<ul style="list-style-type: none"><li>• Landskap</li><li>• Fugl</li><li>• Naturtyper</li><li>• Kulturmiljø</li></ul>	<ul style="list-style-type: none"><li>• Boliger/naboer</li><li>• Reindrift</li><li>• Friluftsliv</li><li>• Reiseliv</li></ul>
Havvind	<ul style="list-style-type: none"><li>• Fugl</li><li>• Fisk</li><li>• Sjøpattedyr</li><li>• Bunnsamfunn</li><li>• Kulturmiljø</li></ul>	<ul style="list-style-type: none"><li>• Fiskeri</li><li>• Sjøfart</li><li>• Forsvarets interesser</li></ul>
Solkraftanlegg	<ul style="list-style-type: none"><li>• Landskap</li><li>• Naturtyper</li></ul>	<ul style="list-style-type: none"><li>• Landbruk</li><li>• Friluftsliv</li></ul>
Kraftledninger	<ul style="list-style-type: none"><li>• Landskap</li><li>• Fugl</li><li>• Villrein</li><li>• Kulturmiljø</li></ul>	<ul style="list-style-type: none"><li>• Boliger/naboer</li><li>• Friluftsliv</li></ul>

Energikommisjonen, basert på informasjon fra NVE og Miljødirektoratet.

### 10.3.7 Greenhouse gas emissions from renewable power generation

A main purpose of renewable power generation is to reduce greenhouse gas emissions. All renewable power generation has a low climate footprint compared to fossil energy. Calculation of greenhouse gas emissions over the life cycle is significantly more complicated than looking at the energy accounts. This is partly due to large differences in the energy source based on where the components are manufactured.

Figure 10.4 shows greenhouse gas emissions in power generation from various energy sources, and is taken from a much cited international source, US National Renewable Energy Laboratory). These figures correspond to the UN Climate Panel's sixth main report from 2022. The lowest emissions have wind power, nuclear power and hydropower (13–21 GCO<sub>2</sub> per kWh), while emissions from geothermal production, solar power and Biokraft are only marginally higher (37–52 GCO<sub>2</sub> per kWh). Greenhouse gas emissions from power generation based on fossil sources such as natural gas, oil and coal are in a completely different order of magnitude (486-1001 GCO<sub>2</sub> per kWh). This should be mentioned that emissions for several of the energy sources, and especially bioenergy and hydropower, vary widely depending on the situation. Emissions from hydropower under Norwegian conditions are consistently lower than what appears in the figure (NVE, 2022).

When it comes to greenhouse gas emissions, nuclear power can be seen as a form of virtually emission-free electricity production, compared to power generation from renewable energy sources.

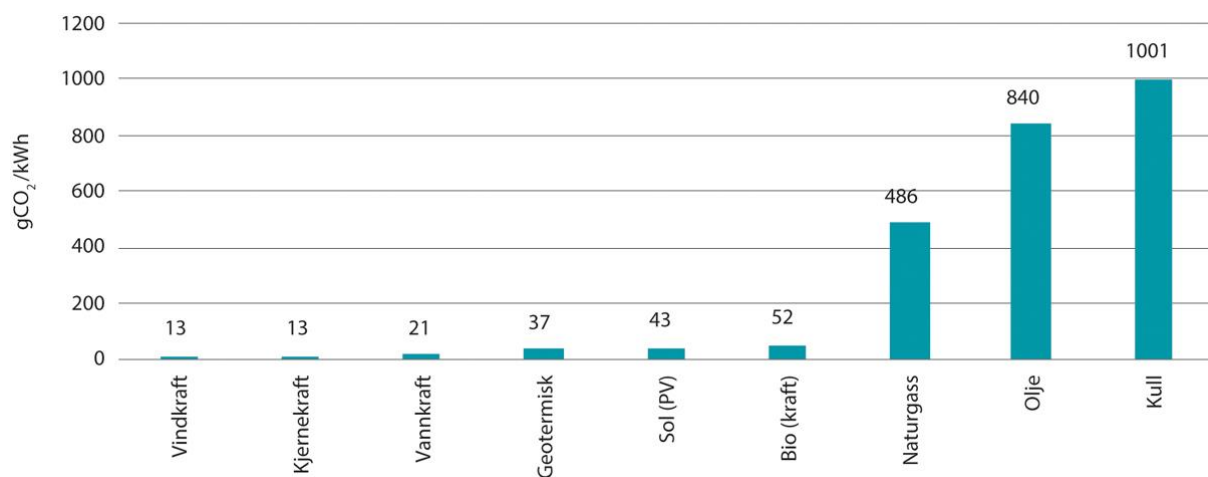


Figure 10.4 Greenhouse gas emissions (GCO<sub>2</sub>/kWh) from power generation over life cycle NVE (2022).

### Box 10.1 Nature and climate are connected

The UN Convention on Biological Diversity, the Biodiversity Convention, was adopted during the UN Environment and Climate Conference in Rio de Janeiro in 1992, together with the Climate Convention and the UN Convention on Desertification. Norway's obligations under the Biodiversity Convention are mainly carried out in Norwegian law through the Nature Diversity Act and Section 112 of the Constitution.

The biodiversity convention has three objectives; To preserve biodiversity, sustainable use of diversity and to just distribute dividends from the use of genetic resources. Based on the Biodiversity Convention, a specific ten-year plan was developed in 2010 by 2020, with 20 so-called Aichi targets. In January 2020, it became clear that none of the 20 Aichi goals were reached. Later that year, Norway, together with almost 100 other countries, declared a global natural crisis.

The main causes of the natural crisis and the loss of biodiversity are the way people use and change land on land and at sea. Over three-quarters of all land on earth, and two-thirds of the sea, are affected by humans. In Norway, the construction of roads and new energy facilities have accounted for most of the reduction in non-interventional nature in recent years.

Many of the land use changes, such as the reduction of carbon-rich areas, also lead to large annual emissions of greenhouse gases. According to the Environment Directorate (2022), the reduction of marsh and peat in Norway in the period 1990-2020 has led to a total emission of over ten million tonnes of CO<sub>2</sub>. In addition to emissions, reduction will provide reduced opportunity for carbon binding in the area in the future. The Environment Directorate has made some serious emission estimates for land use in Norwegian wind turbines. The calculation is based on the general calculation plant designed for land use in Norway. With a life of 25 years for a wind turbine, the calculations show that the carbon emissions from land use are 1.0–3.0 grams of CO<sub>2</sub>/kWh. Emissions from land use come in addition to the emissions from, for example, the production of components and transport.

How we use nature therefore affects the climate, while climate change affects nature. A well-functioning nature in good condition can help us slow down and handle climate change, while maintaining vital natural goods. It is therefore important to solve the climate crisis without strengthening the natural crisis.

In December 2022 in Montréal, the world's countries gathered on a new global nature agreement under the Biodiversity Convention. In the new nature agreement, among other things, the goal has been set to preserve at least 30 per cent of land and sea by 2030 and that all nature should be managed sustainably. In the agreement, there is also a goal that 30 per cent of nature that is currently destroyed will be restored by 2030, and the rich countries have joined forces on a global target of \$ 200 billion in natural financing from all sources, of which 20 billion of which of These will be transfers from industrialized countries to developing countries by 2030.

The new nature agreement can affect the framework conditions for the use of nature. This in turn can have consequences for energy development in the future, which seizes a lot of area and contributes to the loss of natural diversity. In the future, the government will assess how the nature agreement is followed up in Norway, and submit this to the Storting. How protection and conservation can be strengthened will be part of these assessments.

In June 2022, the government appointed a committee to investigate natural risk by model from the Climate Risk Committee. The Nature Risk Committee, until December 2023, will investigate the exposure of the Norwegian industries and sectors to natural risk.

[Box End]

### **10.3.8 The consequences can be reduced through the licensing process**

An important part of the licensing process is to ensure good environmental adjustment of the projects. During the process, the possibilities of avoiding or reducing negative effects on nature are considered. This can be achieved, for example, through good location choices, adaptation of the design of the project and environmental technical solutions.

All licenses for new power generation and grid facilities are given on conditions that will safeguard the environment and general interests. Measures to avoid, limit, mitigate or compensate negative consequences can be imposed on the licensee on the basis of the licensing conditions. For hydropower, wind power on land and power lines, so-called standard conditions have been developed, and in addition, special conditions can be given on

measures according to a specific cost-benefit assessment. The standard conditions also include requirements to prepare a detailed plan to be approved by NVE before construction can begin.

Examples of mitigating measures in connection with hydropower are requirements for the release of minimum water flow on affected river stretches, requirements for high summer water levels in hydropower reservoirs and restrictions on power driving of the power plant to avoid sudden changes in water flow. Other mitigating or compensatory measures that can be imposed pursuant to the standard conditions, for example, are fish passages past ponds, thresholds, biotope -improving measures, incumbarance for waterfalls and facilitation for outdoor activities. When renovating and expanding existing hydropower plants, restoration and rehabilitation of previous natural values in the area may be a relevant measure.

For wind power plants on land, today's standard conditions contain requirements for the appearance and surface of the wind turbines and security measures related to ice cream. In May 2022, NVE sent proposals for a new template for standard conditions in construction licenses for wind turbines on land to the Ministry of Petroleum and Energy (NVE, 2022). The proposal for a new template includes, among other things, distance requirements for buildings and requirements for a detailed plan for the closure of wind turbines. Relevant mitigation measures are assessed in each case. For example, measures to reduce the risk of bird collisions have been imposed.

NVE external report no. 13/2022 provides an overview of the knowledge base for the return of areas when closing the wind turbine. According to the report, there is little experience in what it costs to return natural areas on a larger scale. Because wind turbines in Norway are largely located in hilly areas of the mountain and in coastal areas, the interventions are in many cases extensive, which makes calculated costs of restoration and reversal to be high.

Examples of mitigation measures in connection with power lines are adjusting the route so that red list species and valuable habitats are avoided, reef herding, marking of the phase lines to increase the visibility for birds, and set up so -called bird sticks.

There are currently few licenses for large -scale solar power and offshore wind. Terms and experience from licensing of other energy systems are used when assessing the necessary conditions for safeguarding the environment and general interests.

Knowledge of environmental effects varies greatly. The knowledge of the effects of hydropower is, for example, good compared to recent technologies such as onshore wind power, and especially offshore wind where there is currently little knowledge of the environmental effects. Strengthening the knowledge for these new technologies will therefore be important in order to assess good and cost -effective measures to reduce the effects. The experience is that it takes time to build good knowledge of the environmental effects of new technologies, and to use it in management and decision -making processes.

### **Box 10.2 The action hierarchy**

In connection with the impact assessments of new development projects, the hierarchy of action is a central concept. The hierarchy of action describes a priority order of measures where one should primarily seek to avoid negative effects on important natural values.

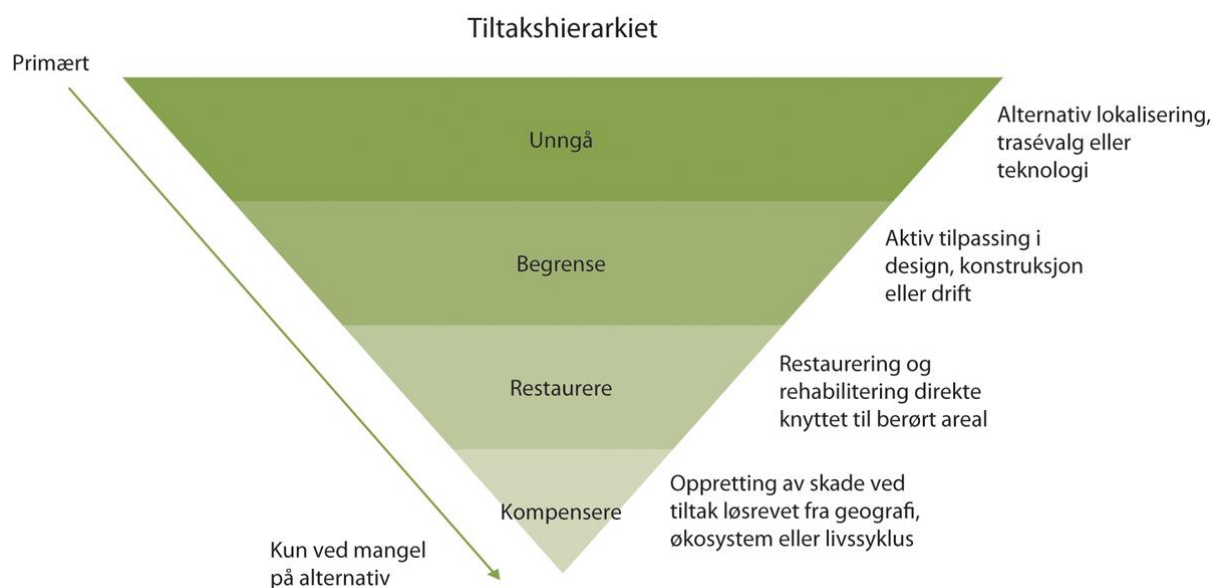


Figure 10.5 Hierarchical presentation of measures to avoid negative influence in development projects

Environmental Directorate.

At the top of the hierarchy are measures that are most relevant in early planning, where an environmental problem can be avoided. Where this cannot be done, solutions must be seen further down the hierarchy, such as measures to limit and renovate the environmental damage. Compensation measures are considered the solution that will normally give the least effect, but such measures are better than not doing anything at all.

Examples of measures that take into account both nature and climate are to avoid interference in carbon -rich areas such as marsh and forest or to concentrate development to areas where nature is already heavily affected or destroyed. Compensatory measures may be the restoration of destroyed natural areas or the establishment of new nature elsewhere.

[Box End]

#### 10.4 Society of society

Hydropower formed the basis for modern Norway and is an important part of our national identity and culture. The Norwegian hydropower resources have provided industrial development, value creation, light and heat for over 100 years.

With the development and operation of power generation and industry follows nature interventions and local disadvantages. Historically, public ownership of natural resources and revenues to local authorities has been important for this being tolerated and accepted. Equally important was that companies created jobs and prosperity development.

Not least, the right of return to hydropower has contributed to legitimacy and acceptance. This was also thoroughly legally defended by Norway in the necessary adaptation to EU law as late as 2007-2008. It also states in the Waterfall Rights Act that the country's hydropower resources belong to the public, and must be managed through public ownership at state, county municipal and municipal levels. The prerequisite that the benefits of natural resources should accrue to the community is alive and relevant in Norwegian society.

These historical experiences and framework conditions can provide guidance on what it takes to gain societal acceptance and legitimacy when it comes to disadvantages associated with the green shift in the future.

#### **10.4.1 The term society**

Social acceptance (or social acceptance) in connection with renewable efforts can be understood as how different social interests relate to a proposed or existing energy project. There is often a distinction between the sub-categories local acceptance, political acceptance and market acceptance. Social acceptance can be linked to several factors that engage different actors in society. There may be players operating at different levels, and where citizens and decision makers can have several roles at the same time. Understanding and recognition of the complexity built into the ambiguous concept of society can be crucial for handling potential and real conflicts related to renewable energy projects.

Many projects face resistance despite significant general political acceptance and support for renewable energy. The perception of unfair decision-making processes and unreasonable distribution of advantages and disadvantages creates challenges for local society. Some projects are never realized, others are postponed due to conflicts and local resistance. How this is handled politically, both between different technologies and over time. People's right to information, access and possibility of co-determination are key principles of our democratic society. Other important principles are the right to compensation, freedom of speech and an impartial legal system. The discussion on societal cases for energy facilities will almost always affect or link to several of these principles (Ruud, Wold and Aas, 2016).

#### **Box 10.3 It has stormed before too**

Norway has many experiences related to societal cases and energy issues. When electricity came to Norway in the second half of the 19th century, it was perceived as a "modern miracle". In the period 1920–1970, there was great development activity to ensure the supply of electricity for both households and industry. Hydropower and electricity production were of great importance to the general welfare development.

But as many watercourses were developed, there was more attention on protection. Extensive development after World War II gradually led to increasing dissatisfaction and higher levels of conflict around the utilization of hydropower resources. The Norwegian environmental movement emerged as a direct consequence of new proposals for the development of new hydropower production in the 1970s. It affected the policy in the field. Throughout the 1970s and 1980s, the protection plan for watercourses and a total plan for watercourses became the very central management tools in energy policy (Angell & Brekke, 2011).

The debate that arose around the development of power lines in Hardanger 30 years later was for many unexpected. However, it shows good importance of society. After several years of major protests and conflicts, in 2010 the government made the decision on the construction of the power lines. The then Minister of Petroleum and Energy Terje Riis-Johansen then stated that "This is a classic conflict in which great TS needs are different from the local wishes" (Aftenposten, 2010). The fight against the so-called "monster masts" has subsequently been described as a social drama.

[Box End]

#### **10.4.2 The resistance to wind power in Norway**

In recent years, the resistance and conflicts have largely been about wind power, especially wind power development on land.

Cicero (Aasen, Klemetsen and Vatn, 2022) have mapped variations in support for wind power development between groups in the population and over time. In 2018, a solid majority (65 per cent) believed that Norway should increase wind power production on land, while in 2021 the proportion was almost halved (33 per cent). Similarly, it is seen that the resistance has quadrupled in the same time period, from 10 per cent in 2018 to 40 per cent in 2021. The proportion who are uncertain or ambivalent has remained stable on about a quarter of the respondents.

The results show no clear differences in attitudes towards wind power on land between gender, educational groups or revenue groups. However, there are quite large differences between age groups, where they under the age of 30 are more positive than the age group 30-44 years, which in turn is more positive than the two oldest age groups. Furthermore, one can see regional differences, but most of these disappear when taken into account centrality: More central areas are more positive about onshore wind power. However, one region still stands out even when taking into account centrality: Southern and western Norway are more negative than other regions.

This study was conducted before the energy crisis in the EU and before the war in Ukraine. This, along with the increased electricity prices that have followed, seems to have affected our attitudes somewhat. In Cicero's climate survey from 2022 (Cicero, 2022), support for land on land has increased to 39 per cent, ie up from 33 per cent the previous year. At the same time, the resistance to expanding wind power to increase power exports is steadily rising over the years.

The support for offshore wind power is higher than the resistance, over all years. In 2018, 72 per cent agreed that Norway should increase the production of offshore wind power, but fell in 2021 to 58 per cent. In the same way as wind power on land, the support in 2022 has gone up again, and is now 61 per cent. The support is highest among young people (under 30) and the oldest (over 60) (Cicero, 2022).

#### 10.4.3 What factors contribute to societal cases?

There are many studies on which factors contribute to societal cases of renewable energy. The EU-funded Winwind project has done a comparative analysis of ten case studies on wind power from different countries in Europe where Norway is also involved. The study has investigated the degree of influence and significance to several different drivers who have had a role when it comes to coming across obstacles to societal acceptance for land on land. Table 10.3 shows the most important driver categories that the project has identified and the overall significance of specific drivers.

Table 10.3 The importance of various drivers for societal acceptance of wind power on land

Kategori	Driver	Nummer <sup>1</sup>
Tekniske kjennetegn	Teknologisk innovasjon	4
Miljø	Landskap	9
	Biologisk mangfold	8
	Drivhusgassutslipp	4
Økonomisk deltakelse	<b>Påvirkning på den lokale økonomien</b>	<b>18</b>



	Aktiv økonomisk deltakelse	8
	<b>Passiv økonomisk deltakelse</b>	<b>17</b>
Individuelle kjennetegn	Identifisering og eierskap	7
Prosessuell deltakelse	<b>Åpen og ærlig kommunikasjon</b>	<b>20</b>
	<b>Formel prosessuell deltakelse</b>	<b>14</b>
	<b>Uformell prosessuell deltakelse</b>	<b>17</b>
Marked	Forsyningssikkerhet	7
Styring	<b>Politisk lederskap</b>	<b>14</b>
Tillit	<b>Troverdighet og tillit</b>	<b>13</b>

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1 The higher the number, the greater the importance of this driver. Drivers with the greatest importance are highlighted.

Rambelli and Hinsch (2019).

The analyzes from the Winwind project indicate that open and honest communication together with early and real participation in the planning and decision-making processes are very crucial to promoting societal cases. Other important factors are financial participation, for example through local ownership of the projects, financial compensation or the projects promoting local value creation and employment. Political leadership and trust in authorities and developers are also important factors. Another comparative review of 25 case studies on societal cases of renewable energy in the European countries underpins many of the findings in the Winwind project (Segreto et al., 2020).

The analysis from the individual countries shows that there are many common features between the countries when it comes to drivers for society, but also that there can be quite large differences in the conditions that are emphasized. In Norway, particularly physical interventions, which affect the landscape and which lead to increased traffic and noise, have great importance. Visibility of the wind power plants and effects on biodiversity are other conditions that are emphasized. However, since the data from the analysis is based on wind power projects in central Norway, it is not certain that they are equally representative of all regions.

#### 10.4.4 Ownership and Economy

In Norway, ownership of the wind power and fair distribution of income has been advanced in the change of word. The wind power plants are owned and operated by both Norwegian and foreign companies. In 2020, about 38 per cent of ownership of wind power was Norwegian, of which a large proportion of state. Just over 60 per cent were owned by foreign companies (NVE, 2020). Many of the wind turbines that have been under construction in recent years have been owned by foreign companies (NRK, 2020), and the ownership overview may thus have changed. However, the figures show that foreign companies are left with a significant proportion of revenues. Some have therefore advocated the introduction of both requirements for public ownership and return for wind power, corresponding to the

hydropower schemes. For example, LO believes that production from various renewable sources, such as water and wind, must be equated with regard to ownership, tax, return and local compensation (free trade union movement, 2022).

The Storting decided on December 14, 2021 to introduce a production tax on land-based wind power, applicable from 1 July 2022. The production fee includes all land licensed onshore wind turbines, ie all wind turbines on land larger than five wind turbines or have more than 1 MW installed capacity. The proceeds from the fee accrue to the state, but will be distributed to the host municipalities. The fee is a financial compensation to municipalities that make land available for the production of the large community and which is expected to strengthen the local anchorage for wind power.

In the treatment of the state budget for 2023, the Storting adopted the Government's proposal to increase the production fee on land-based wind power from 1 to 2 øre/kWh. The government has also proposed to introduce a basic interest tax for land-based wind turbines from 2023 and a new natural resource tax for wind turbines of 1.3 øre/kWh, where 1.1 øre goes to the municipalities and 0.2 øre goes to the county municipalities. Both the production fee and the natural resource tax are proposed to be deducted to deduct krone for the krone in the basic interest tax. The proposal is now for consultation.

For hydropower, the effective basic interest rate rate increased from 37 per cent to 45 per cent from the 2022 income year.

#### **10.4.5 How to achieve popular support and acceptance?**

Most studies conducted have primarily looked at the factors that contribute to societal cases of planned energy projects. The challenge in the future is on a different scale: How to achieve popular support and acceptance for the pervasive energy conversion we face, and which will have major consequences for both nature and society.

The implementation will depend on whether people have confidence in the decisions that need to be made by politicians and authorities. Norwegian citizens generally have great confidence in various political institutions and authorities compared to other European countries (Statistics Norway, 2016). But trust is fresh and can change rapidly. For example, the very high electricity prices have recently helped to put confidence in both climate and energy policy to the test (energy and climate, 2021).

The OAG has previously pointed out that there is a lack of political clarification of the ambition level for the development of renewable energy in Norway, and how the authorities should facilitate the realization of the change in the energy area (the OAG, 2014). An important reason for the survey was Norway's obligation through the EU's renewable directive to increase the renewable share to 67.5 per cent in 2020 and the establishment of a common electricity certificate market with Sweden as an instrument. The aim of the survey was to assess the extent to which the Ministry of Petroleum and Energy facilitated an effective concession and complaint case that safeguards the goal of increased renewable energy production. The OAG believed that lack of clarification at the overall level creates room for principled discussions in each development case. Lack of clarification of how energy needs should be weighed against other societal interests also provide a large room for difficult judgment assessments, which can contribute to a higher level of conflict and greater scope of complaint. The OAG's criticism has mainly been followed up through measures in the energy report, Report. St. 25 (2015–2016).

#### **Box 10.4 Policy is challenged**

In the book *The Windmill Fight: History of a People's Rebellion* (Totland, 2021), the author has had conversations with wind power opponents throughout Norway. The author's starting point has been to understand the resistance to wind power that has been characterized by steep fronts, polarization and distrust.

According to the author, the change of mood happened when the national framework for wind power development was presented by NVE in 2019. Suddenly everything became very concrete. For people who found their own neighborhoods marked as most suitable for wind power, the warning lights started to flash. The resistance to wind power grew.

The author conveys in an interview with Enerwe that there are many underlying causes of the resistance to wind power. A major problem seems to be that there is a lack of a overall narrative and a credible explanation for why we build wind power in Norway. Although politicians have tried to say that the wind power development has had broad political support, the impression is the impression that they have left everything to the bureaucracy. When the national framework for wind power met resistance, apparently everyone with political power let the ball dead (Totland, 2021) (Enerwe, 2021).

[Box End]

There are many controversy and dilemmas related to the energy conversion, and there are probably no simple or quick solutions to ensure broad support in the population. However, many people seem to agree that a clear and well -justified energy policy is crucial to building societal cases and confidence in the difficult decisions that need to be made. Other conditions that are often highlighted as important for increased acceptance, especially in connection with wind power, are more open and inclusive processes rooted in municipal planning, changed taxation so that the host municipalities get more left for the areas that are made available, and greater weight on Environment and local effects in the concession treatment.

The wind power message (Meld. St. 28 (2019–2020)) describes a number of specific measures to improve the concession treatment of wind power, including to increase the population's confidence in the process and the authorities. In a new licensing scheme for wind power, the county council and the municipalities are given an extended role and will be consulted in the reporting and application phase of a new wind power project. A process has been initiated to incorporate planning and construction of wind power plants in the Planning and Building Act.

Measures to improve the licensing treatment include:

- Guidance on the concession process should be strengthened, so that the local community, local and regional authorities and others will get better information on wind power cases. Good and thorough guidance should provide predictability to all actors participating in one or more phases of a licensing process.
- Neighbors around planned wind turbines should be actively involved in the consultation processes, and better routines for neighbor notification will be introduced.
- Reindeer husbandry should be actively involved in an early phase and participation throughout the process, also in impact assessments. Licensing applications with documentation on participation and agreement on mitigating and compensatory measures shall be given priority in the concession treatment.
- A sharp time course with new deadlines to ensure that projects are more predictable to deal with for municipalities and locals.
- Introduction of a minimum distance from wind turbines to year -round housing and recreational buildings.

Although measures such as the improvement of licensing processes and local skills Nsation can lead to a greater degree of acceptance, however, there will be dilemmas related to increased development of renewable energy compared to the damage this will cause to nature. Understanding people that we not only have a climate crisis, but also a natural crisis, has contributed to the desire to preserve nature itself has become stronger. The question of acceptance is thus also about real concepts of goal and different views on how they should be handled.

Several have advocated a more planned and holistic approach as a possible way to go. Professor of renewable energy at NMBU, Kristin Linnerud, proposes to prepare a plan for the power requirement in Norway, with the aim of creating an understanding of the utility of increased power development, for example by linking wind power development to specific measures to reduce greenhouse gas emissions and efforts that create New economic activity and workplaces (Linnerud, Post for the Energy Commission, 2022).

In the Hurdals platform, the government parties have referred to an ambition to develop an overall plan that covers both Norwegian hydropower, wind power, solar power and other energy and infrastructure developments that require a license (Government, 2021). Details of what a unified plan should contain or how it should be implemented has not yet been published.

#### **Box 10.5 Can wind turbines be built in less conflicting areas?**

Several environmental organizations believe that wind power on land should be built elsewhere than in untouched nature and areas that are important for natural diversity and outdoor life. These can be areas along highways, in connection with industrial areas or other places where the natural values are already impaired. In addition to this will reduce the burden on nature, the assumption is that it can also cause minor conflicts. The recently opened Lutelandet wind turbine in Fjaler municipality is an example of a facility located in close proximity to a defined industrial area, which thereby links wind power and industrial development together.

According to NVE, such developments may be the best seen from a natural perspective, while also being well adapted to the power grid. Nevertheless, there may be special challenges related to the location of wind power plants in already developed areas. This applies, among other things, to distance requirements for buildings, noise and safety considerations. Applications NVE has been processed for wind power plants near highways and industrial areas show that such developments can also be quite conflicting with many objections (Europower, 2019; the Storting, 2020). For example, visibility is likely to be greater because the wind turbine is located in areas where people are staying, such as a place of work or travel.

[Box End]

#### **10.4.6 The role of the municipalities**

Predictable framework conditions (including taxes) for wind, water and sun will be of great importance for the ability and willingness to invest in the players and the municipalities' ability and willingness to promote new projects.

Establishing the renewable power of the future will take place in a municipality. Development of both hydropower and land on land involves interference with nature and the environment and local disadvantages. Already during the formation of the hydropower regime, the current schemes with the right to concessionary power and licensing fees to the

host municipalities were established. It was an expressed goal that the affected communities should retain a proportion of value creation from their natural resources.

Our recent wind power history has shown that without local anchoring and acceptance, the green transition can hardly be carried out, and at least not with the speed our climate obligations impose on us. This is also the reason why the government in April 2022 emphasized that the reopening of the concession processing of wind power cases can only take place where the affected municipality agrees.

There is a broad consensus that the support of municipalities affected by major power projects is a crucial prerequisite for the implementation. In the public change of word and in public investigations, it is consistently that incentives are needed, that those who take on a burden should also take part in the upside and that the local anchorage must be in place.

Based on our climate obligations and power requirements in the future, it is not only a challenge to secure the necessary basis for more renewable power generation, but it is also a major challenge to gain the pace of the renewable development. It places great demands on streamlining our licensing processes. Here, experience shows that the clearer the positive, local effects of a development, the lower the degree of conflict and faster the process goes. The incentives will help reduce the risk of the role of host municipalities becoming a major barrier for increased production of renewable power.

The consideration of the affected communities is also studied in the European context. For example, it is stated in NOU 2012: 9 The energy assessment, Chapter 6.5:

"From EU teams, it is emphasized that one of the largest barriers today towards the transition to renewable energy is resistance from the environments that must refrain from their natural resources and which are directly affected by lasting nature interventions (RebelGroup, 2011)."

This is in line with the experiences we have for generations from the hydropower sector and recent experiences from the wind power sector. A more than hundred -year hydropower regime with its own rules to safeguard the affected communities has proven successful and has led to the fact that the hydropower development has largely been supported by the resource districts. We have had the opposite experience in recent years in the wind power sector, with strong and increasing local resistance. The wind power sector has not had similar schemes that are hosted by host municipalities, such as the hydropower sector.

Hydropower: The hydropower development that will be most relevant in the future will be of a somewhat different character than our traditional hydropower. Whether this states a unanimous selection in NOU 2012: 9, Chapter 6.5:

“There is reason to raise questions about the institutional schemes that are historically established around the hydropower, are equally suitable for organizing the value of value between the state, developer and affected district for the renewable policy of the future. The current distribution schemes, which until today have been common agreement, are based on the properties of traditional hydropower plants and are not as relevant for tomorrow's hydropower plant- pump power plants, power and river power plants. Increasing local opposition to new hydropower plants has been registered in such conditions. ”

This suggests that the current hydropower regime is reviewed to better absorb both today's and tomorrow's development. An example of today's licensing and tax regime is not adapted to the hydropower development we will look forward to is the rules on natural resource tax. The natural resource tax is calculated by total power generation, section 18-2 of the Tax Act. Total production for the power plant will be reduced by pumping power and this will affect

the calculation of the natural resource tax for the current power plant. Lower net production provides a lower basis for natural resource tax. Another example is concessionary power. The reduction, where the rules require a watercourse regulation and where renovation and expansion projects have been shown to lead to a higher concessionary power price without corresponding amount of concessionary power for the host municipality.

On the other hand, such investments differ from traditional hydropower developments. It is not in the same way new developments and interventions in pristine areas, but the development of existing power plants that already generate some large revenues for the host municipalities. Power power plants, pump power plants, etc. is believed to increase the value of existing power plants. It can increase the host municipalities' income through the property tax. As long as the income from pump power exceeds the costs, it will in isolation increase the property tax basis, provided that the power plant is not bound by the minimum or maximum property tax rule. However, increased basic interest tax, which is deducted from the property tax base, is moving in the opposite direction.

Wind power: It is now being established a new license and tax regime for wind power on land where local acceptance lies as an important premise. In this context, the government in connection with the state budget 2023 has proposed that a larger proportion of revenues from wind power on land accrues to the municipalities, including through increased production tax to host municipalities, a natural resource tax to municipalities and county municipalities, and which is included in the equalization of income, and a proportion of the basic interest rate taxation. which goes to distribution among all municipalities in Norway. Wind turbines also pay property taxes in municipalities where this is printed.

With the notified changes, there is a development of the framework conditions for wind power that is based on several of the elements that we know from the hydropower regime. Although the nature interventions are different, in both cases it is the utilization of a valuable and limited natural resource and production of the same item - a kilowatt hour - and turnover of this item in the same market. Wind power on land is now less expensive to develop than hydropower. The foundation wall of this regime is that parts of the value creation are reserved for the municipalities that have refused their natural resources.

Lasting and predictable incentives: Norway has a fragmented municipal structure, and where the population can vary from a few hundred inhabitants to several hundred thousand. Our large hydropower plants and the larger wind power plants are generally located in pig -ranked areas, and the host municipalities for these plants are often characterized by few inhabitants, but large areas. In the municipal economy context, this can lead to some small municipalities having higher income than other municipalities.

In its report, the revenue system committee (NOU 2022: 10) emphasized that many municipalities have high revenues from, among other things. Hydropower, aquaculture and petroleum that increase the differences between the municipalities. The Committee recommended that "the recipient municipalities should still be left with a significant part of these revenues, but that the consideration of equal services indicates that parts of the income should benefit all municipalities. The Committee therefore recommends that a separate, moderate leveling scheme be introduced for these revenues, with a 10 per cent symmetrical leveling. "

The government emphasized in the Hurdals platform that "the government wants to ensure that local communities that make their natural resources available for development are given more again for it and are ensured a legitimate part of value creation, including through changed taxation of wind power." The Brandtzæg Committee (NOU 2020: 12) also stated

that the revenue system must provide the district municipalities sufficient incentives to facilitate value creation. The committee further wrote that “Natural resource revenues should nevertheless be disconnected in whole or in part from the equalization mechanisms in the income system. In order to ensure acceptance and support for business activities that involve major interventions in nature and incur costs to the local communities, it should be used through statutory schemes a performance-to-performance principle where the host municipality gets something left to make nature available to the large community. Local taxation when utilizing local natural resources is a targeted measure that can help realize national climate goals through better utilization of renewable energy sources.”

### 10.5 What is expected of new power generation?

Both NVE and Statnett's long -term market analyzes require that new power generation be invested in Norway by 2040 and 2050. The analyzes require political decisions on new production, especially in the long term.

The Energy Commission has studied the long -term energy market analyzes of NVE (2021), Statnett (2021) and DNV GL (2021).

The analyzes differ from each other, among other things, in the assumptions of the policy that will be carried out in the years to come, including the extent to which licenses are granted to wind power on land. A particularly important difference is whether the analyzes assume that a policy is implemented that makes the climate goals reach. Statnett's analysis shows what it takes to reach Europe's climate targets, while NVE's analysis assumes a continuation of today's instruments. The long -term analyzes are also all published before the invasion of Ukraine. Some of the difference in the assessments of the development of wind power, both on land and at sea, may be due to the analyzes being performed at different times.

The Energy Commission's reading of NVE, Statnett's and DNV GL's long -term power market analyzes shows that it is the extent of wind power that mainly makes the difference in expected power generation going forward.

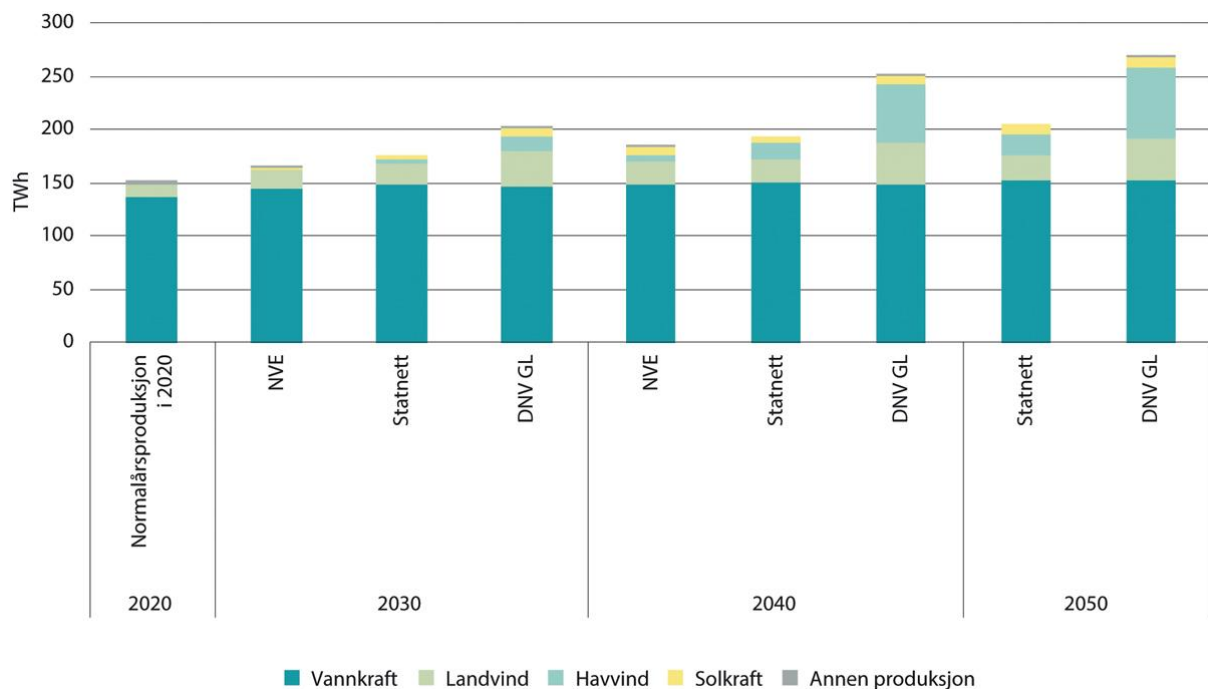


Figure 10.6 Power generation in long -term analyzes

NVE, Statnett and DNV GL (all 2021).

It seems to be agreed that the potential for increased power generation from hydropower is present, but that it is limited. All analysis environments expect some growth in hydropower.

Solar power is also expected to increase, and the analysis environments are quite in agreement on a volume of about 10 TWh towards 2050 (NVE expects 7 TWh in 2040). This is a great growth compared to today's installations of 0.15 TWh.

There is a large gap in the assessments of the further development of wind power on land in Norway. While NVE expects a smaller increase between 2030 and 2040, Statnett and DNV GL have a significant increase in land on land.

Table 10.4 Power generation in long -term energy market analyzes. TWh

	2030			2040			2050	
	NVE	Statnett	DNV GL	NVE	Statnett	DNV GL	Statnett	DNV GL
Vannkraft	145	148	148	149	150	149	152	152
Vindkraft på land	18	21	32	21	23	39	24	40
Havvind	0	4	14	7	15	54	20	67
Solkraft	2	3	7	7	5	8	10	9
Annen produksjon	1	0	2	1	0	2	0	1
Sum	166	176	203	185	193	253	206	269

NVE, Statnett og DNV GL (alle 2021).

Also, when it comes to sea power, there are large variations in how much is expected, which is due to different assumptions about how quickly such power plants are established. For offshore wind, the uncertainty is also greatest, as the framework is still under development.

Such analyzes can be accurate in the first years, because then much is known. Among other things, it can be assumed that power plants under construction will be completed and that it is likely that projects where investment decisions are available will be realized. It is also possible to make qualified guesses of the proportion of power plants with a license that will be built. Further in, it depends more on what political choices are made and how consumption, technology, costs and market prices are developing. With 2050 as a horizon, there is much that is possible, and especially the policy will have a decisive impact on what power generation in Norway looks like.

### 10.5.1 A review of several analyzes

In the article "Long-Term Trends of Nordic Power Market: A Review" reviews Chen et. eel. (2021) 43 scenarios in 15 long -term power market analyzes for Nordic countries and for the Nordic countries as a whole.

The power market analyzes studied are published between 2016 and 2020, are publicly available and mainly published by energy authorities, central grids and IEA. The comparative



study finds, among other things, that there is great variation in how much wind power is assumed in the various analyzes/scenarios. Everyone has assumed that there is less wind power than the market would have chosen given the power prices that appear in the analyzes. Among other things, social acceptance limits the scope entered into the power market analyzes.

### **10.6 Potential and opportunities for increased power generation**

The division of labor in the power system is such that it is the market participants who decide on investment in new and existing power plants, while the authorities decide whether projects should be granted permission.

In addition to assessing licensing applications, the authorities have instruments to facilitate new power generation. Among other things, the policy in other areas of society affects the opportunity room, such as nature and environmental policy. Access to power grids is also important. During periods, there has been support for development, including through the electricity certificate system, but now only solar power gets direct subsidies, this through Enova.

The most concrete and safest potential for new power generation is made up of the projects that have a license, but which have not yet been put into operation. Throughout the year, NVE publishes a total quarterly overview of the status of the concession treatment (NVE, 2022).

At the beginning of the second half of 2022, 407 power plant projects had a license, but which was not yet put into operation. Of these, 66 projects were under construction, divided into 4 wind power projects and 62 hydropower projects. The four wind power projects had an expected annual production of over 2 TWh, while the hydropower projects had a total expected annual production of slightly above 1 TWh. These projects will probably be completed and put into operation.

Somewhat more uncertainty is raised by the 341 projects that had a license, but where construction had not yet started. This applies, among other things, to 9 wind power projects with an expected annual production of 2 TWh and 273 small power projects with an expected annual production of 1.9 TWh. There are also some projects in larger hydropower. There may be various reasons why the projects have not started construction, such as that investors do not see profitability in the projects or that there is not sufficient grid capacity. Concessions lose their validity if the power plant is not built within a certain time, and there is reason to believe that part of this potential will not be realized.

In total, theoretically can be realized 9 TWh of new power generation based on given licenses, but it must be reserved that part of this cannot be realized for various reasons.

NVE also publishes an overview of cases for consideration, gathered over all stages in the licensing process. Overall, at the beginning of the second half of 2022, there were cases of new development with the energy authorities with an estimated annual production of about 25 TWh. Most of this is wind power projects. Some of the projects will be denied the license application, or be deducted by the applicants for various reasons.

#### **Box 10.6 What is a potential?**

The lexical definition of "potential" is opportunities or resources, and is a widely used term in energy policy discussions. The term is also used here, but what is meant by a potential when analyzing the energy system of the future?

It is the physics that provides the starting point for assessing whether there is a potential to reduce energy consumption or to produce renewable energy. For example, it is possible to calculate the physical possibility of producing power of all water that falls over Norway in the form of rain or snow. NVE has calculated this option for 600 TWh/year, ie more than four times as much hydropower as producer Eres today.

We can call such opportunities theoretical potentials, which indicate the upper limit on how much can be realized in savings or production.

Both technological, economic and politically specific limitations must be taken into account before anything can be expanded, and therefore it should not be too much emphasis on theoretical potentials. In addition, even if something is technically possible and economically sound, to varying degrees take some time before a potential can be realized.

Technical-economic potentials are often used to describe what is possible to realize, given technical limitations and within defined economic frameworks. Often, political restrictions are taken into account in technical-economic potentials. For example, the technical-economic potential for hydropower in the Storting report Kraft for change (Ministry of Petroleum and Energy, 2015) to 212 TWh/year, of which around 50 TWh/year is protected through the protection plan for watercourses. This potential includes what has been developed, and the potential depends on the cost limit set for the projects. Potential studies normally consider average, total annual production, and do not distinguish the quality of production (including the distribution over the year).

For wind power, the technical-economic potential will be very large. It is the political restriction through the licensing system that determines how much wind power can be expanded.

Solar power has had a rapidly falling costs, and if this continues, it will soon be profitable to expand large solar power plants in Norway. The technical-economic potential for solar power will thus quickly go from being quite small to becoming very large. For solar power, the policy through the licensing system is also crucial to what becomes possible to realize.

[Box End]

### **10.6.1 Hydropower**

Hydropower still has a development potential. Projects that can deliver more power, projects that increase their efficiency in existing plants, and projects that can increase storage capacity may be relevant. The owners of hydroelectric power plants are professional, and invest in maintenance and upgrades to ensure the best possible efficiency and to maintain production capacity. This is in the owners' interest.

However, the Norwegian hydropower is constantly evolving. At the beginning of the second half of 2022, there was more than 3 TWh new hydropower production during concession treatment (NVE, 2022).

New hydropower production can come in existing plants or in connection with these, and is referred to as renovation and expansion. Upgrading applies primarily to the electrical and mechanical equipment and provides small or no new environmental effects, while extensions involve higher utilization of the water resource or the supply of more water. The potential for such upgrades and extensions is assessed by NVE. Over the past 20 years, about half of Norwegian hydropower production has gone through some form of renovation and/or expansion. This has increased production by close to 5 TWh. NVE estimates that the overall potential for further renovation and expansion is 6-8 TWh (NVE, 2022).

NVE also estimates that turbine upgrading in isolation and theoretically can result in increased production of 4.4 TWh due to improved efficiency. This will be partly included in the potential of 6-8 TWh, that is, it will be partly included and partly come in addition. Therefore, it is not considered in terms of finances.

There is also a potential for brand new hydropower plants. In the parliamentary report Kraft to change from 2016, the Ministry of Petroleum and Energy pointed out that the potential in the form of new projects over 10 MW summed up about 8.3 TWh. This is mainly the sum of specific projects that were mapped through the work on the total plan in the 1980s.

The potential for small power has been mapped digitally. At a cost limit of up to NOK 5/kWh, which corresponds to LCOE of approx. 37 øre/kWh, the potential in 2015 was assessed at 5.7 TWh. By an LCOE of approx. 70 øre/kWh rises the potential to 23.2 TWh (Ministry of Petroleum and Energy, 2016). In its input to the Energy Commission, the Småkraftforeninga pointed out that there is a potential of 13-14 TWh new small power.

NVE's estimates are technical-economic potential where the costs are assessed and where the potential covered by the protection plan for watercourses has been removed. Previous estimates assess the potential of the protection plan for watercourses for around 50 TWh.

There are other and more expansive estimates for how much Norwegian hydropower production can be increased. Such estimates do not take into account the finances or protection plan for watercourses.

Much of the hydropower is adjustable, but it can also be more adjustable. It is possible to increase the effect so that the energy can be produced faster and thus increase the contribution to balancing the system. Rebuilding to pump power plants can also have more effect. At low prices, the top magazine can be filled and then drained when the price becomes high. Such developments no more energy, and the potential cannot be expressed in TWh. Several studies of these opportunities have been done.

A situation ahead with larger fluctuations in prices and larger price differences will make it more profitable with power extensions and pumps in the hydropower system. Several pumps and pump power plants in Norwegian hydropower can also contribute to better security of supply, using cheap unregulated power to pump, thus increasing the filling degree in the magazines.

The hydropower industry is covered by several different schemes that provide revenues from hydropower production to the state, municipalities and county municipalities. In addition to the ordinary corporation tax they are t basic interest tax, natural resource tax, concessionary power and license fee, as well as property tax. Taxes The companies face should not weaken the investment incentives, but ensure that investments that are profitable before tax are also profitable after tax. Gross -based elements, such as property taxes, licensing fees and concessionary power, do not depend on profitability, and will thus increase the companies' sales price requirements before an investment is profitable. This is discussed in the report from the expert committee that assessed taxation of hydropower plants (NOU 2019: 16 Taxation of hydropower plants).

### **10.6.2 Wind power on land**

Wind power on land went a few years ago from being a technology with many unrealized licenses that were helped with public instruments to become a profitable production technology expanded where allowed. At the same time, wind power went from being a technology with strong political support to being the subject of great popular protests.

The Solberg government proposed in Meld. St. 25 (2015–2016) Power for change to establish a national framework for wind power. At the same time as the hearing in 2019 by NVE's proposal for such a national framework, the concession treatment was paused. In 2020, the Storting dealt with its own parliamentary report on the concession treatment of wind power, which included a number of tightening in practice (Ministry of Petroleum and Energy, 2020). It was opened for licensing of wind power cases in April 2022, provided that the host municipality wanted it. There is still interest in developing wind power projects in Norway, which turns out that some reports of larger wind turbines have been received to NVE. Interest can also be affected by the government's proposal for tax and increased production tax in the state budget for 2023.

Today, wind power on land is the production technology with the lowest cost per kWh in Norway. Wind power on land can also be realized quickly compared to sea power at sea. Wind power production is greatest in winter, which is favorable in terms of the profile of the Norwegian power use and for profitability.

It is not possible to determine the technical-economic potential for wind power on land in Norway, except that it is very large. The technical potential is limited by access to power grids, but there is not a meaningful restriction within the Energy Commission's time horizon towards 2050. This means that it is primarily framework conditions and licensing policy that limits the development, although profitability can also become a limiting factor after Each as more wind power is expanded.

Wind power on land has so far in Norway been built as a larger facility, although there are some smaller wind turbines. It may also be relevant in the future to build small wind power plants, so -called nearby winds.

Within the Energy Commission's time horizon, considerable reinvestments in the wind turbines will be required now. The technical life of modern turbines is normally approx. 25-30 years, and the licenses are given with a duration of up to 30 years. In order to maintain the current level of production for wind power, a new license must therefore be granted, and reinvested in, existing wind power plants until 2050.

### **10.6.3 Wind power at sea**

Norway is a harbor. We have a long history of trade and fishing at sea, and two generations' experience with petroleum extraction at sea. With such a starting point, it is obvious to Norway to explore the possibilities of sea energy. The power situation in Norway has also evolved so that we will need the sea effort to ensure the Norwegian supply of power.

Norway aims to facilitate the supplier companies for oil and gas to have more legs to stand on. Ocean wind represents the greatest opportunity. There are extensive plans for offshore wind development in our neighborhoods and several Norwegian companies already have large deliveries. To develop and strengthen this position, the development of a domestic market is crucial. The project "Delivery models for offshore wind" (Norsk Industri, 2021) aimed to develop delivery models and work for increased execution capacity in order to be able to expand offshore winds on a larger scale on the Norwegian continental shelf, and at the same time increase competitiveness in the international market.

Bottom wind power has quickly become a technology with widespread, especially in Europe, and costs have fallen rapidly. There are now close to 6,000 wind turbines connected to the network in European oceans, with a total performance of over 28 GW. The European Commission has an ambition to reach a total installed performance of 300 GW by 2050. Belgium, the Netherlands, Germany and Denmark in May 202 agreed on a common target for a total of 150 GW by the 2050 (Esbjerg Declaration, Declaration 2022). In comparison, total

performance in the Norwegian power system is approx. 34 GW. The countries and the EU have also set goals for 2030.

The framework for offshore wind power in Norway is under development. Although two areas are open to offshore wind, the licensing processes have not started, but the government has announced that area on southern North Sea II and Utsira Nord will be awarded during 2023.

Two main issues are for investigation and clarification with the authorities: How the area should be allocated, and how the power grid at sea should be developed. See further discussion in Chapter 10.1.3.

In August 2021, the Ministry of Petroleum and Energy works, and in August 2022 a consulting assignment on the design of auction and support models for southern North Sea II.

The Ministry has established three working groups under the leadership of the Ministry, the Norwegian Industry and Statnett who look at coexistence, industrial development and the network. Statnett leads working group 3 where Statnett, together with the industry, looks at the network needs and the interface between Statnett and the players.

NVE and RME have been given three major investigative tasks related to the further development of offshore wind in Norway.

- Effects on the power system of different grid solutions for sea power. In this assignment, NVE will consider the impact on the power system Fram Mo T 2050 at various grid solutions for offshore wind, including Hybrid solutions where power can also be exchanged against other countries. The final report will be delivered in February 2023.
- Regulation of network at sea. RME has been commissioned to assess market design, distribution of bottleneck revenue, coordination of networks and the legal framework for economic regulation of network to offshore wind. In line with the revised deadline, the final investigation will be presented in two parts, one December 2, 2022 and one 3 February 2023.
- Identification of new areas at sea. In this assignment, NVE will propose new areas for offshore winds in Norwegian ocean areas. They will also consider the 13 areas that have been assessed in consequence, but which have not been opened. The report will be delivered by April 30, 2023.

Technology and costs are also under development. Business and industrial players point to great opportunities in Norway, both for large power generation and export revenues from the sale of goods and services related to offshore wind. At the same time, much is unclear about the road ahead for offshore wind in Norway.

Currently, the cost of sea power is higher than the alternatives on land, but also offshore wind costs are falling.

Sea wind power has some major benefits that make the technology attractive and that can partly weigh up for higher costs. First, there is a great degree of freedom in the placement of wind power in the sea, especially for liquid technology. There are also environmental and business interests at sea, but there are still greater opportunities to minimize the influence of interests other than on land development.

Second, wind power has at sea high use and a relatively large proportion of winter production. It is beneficial considering the profile of Norwegian power use.

The technical potential for offshore wind power is virtually unlimited, but it is uncertain when it can be expanded in Norway without public support. So far, grants related to technology development have been provided.

The opened areas Utsira north and southern North Sea II have upper limits of 1500 MW and 3000 MW of wind power respectively. A total of 4,500 MW will, if the use time is 4000 hours, will provide an annual production of up to 20 TWh.

The government has announced that they will allocate land on Utsira north and parts of southern North Sea II in 2023. It is not clear whether support will be provided for development, but it is obvious that at least the development of Utsira north, which has depths that have depths Requires liquid turbines will require a form of subsidies.

The Government Støre has set the goal that it should be opened and allocated area at sea, which can provide 30 GW of wind power capacity by 2040. This corresponds to a normal year production of 120 TWh at a useful time of 4000 hours, ie a power generation of the same order of magnitude as today's power generation on land in land in Norway.

Ocean winds are often built in very large projects quite far at sea, but smaller power plants can also be built closer to land. The developments far offshore are particularly dependent on dedicated web solutions.

It may be desirable to have a certain geographical spread of wind power, also at sea, to reduce the risk of simultaneous - especially for simultaneous low wind power production. Our neighboring countries are expanding a lot of offshore wind in the North Sea, and Norwegian offshore wind facilities far south in Norwegian sea areas will have a high degree of concurrency with other offshore wind production. This must also be seen in light of access to power grids. In the event of a large development of offshore wind, which will be brought to land in Norway, the Norwegian power system also receives a lot of power delivered in a few points, which can present challenges in the event of outcomes.

The state has a greater role than in power generation on land, where the state's role in a specific development case is mainly limited to the question of whether it should be granted a license or not:

- First, it is the state that allocates land to sea power at sea. Access to land is normally something that is agreed with private landowners in the case of power developments on land, although in some cases the area is expropriated.
- Secondly, larger offshore wind power buildings are more than projects on land dependent on connecting to the network that are specifically built for that purpose. Such a network can be radials for direct connection to the network on land, it may be networks connected to several countries (hybrid networks) or it may be a masked network that several countries collaborate on. How this is designed is of great importance to the market value and profitability of the projects.
- The state also has the normal role of licensing authority to weigh the advantages and disadvantages of the developments and determine mitigating measures.
- The state also gets a possible fourth role if support is to be supported for offshore wind developments, for example through long -term contracts/differential contracts.

In order for Norway to succeed in the development of offshore wind power, the state must take a more active role than in the case of development cases on land. It requires clear goals for the initiative. If it is quantified how much to be expanded and what are the goals of the initiative, it will give direction to the many state decisions that must be made. The Energy

Commission notes that there are currently only targets for the allocation of area of a large scope.

#### **10.6.4 Solar power**

Solar power can make an important contribution to the power supply in Norway. Solar power is scalable and can be built quickly. Solar power can be distributed both on housing and commercial buildings, and in the form of large power plants. Production comes outside the high load hours, but in interaction with the water reservoirs, solar power can also be important in Norway as well.

The technical potential for ground -mounted solar power is calculated by Multiconsult, on behalf of the solar energy cluster (Multiconsult, 2022). The analysis is based on an assessment of which areas have the least impact on the environment and society. On the sum of agricultural land that may be out of operation, parking spaces and completed landfills, Multiconsult found a potential for 144.1 GWP (Gigawatt Peak) and an annual power generation of 133.3 TWh. Closed gravel roofs, such as Furuseth solar power plants in Greater Elvdal are partly built in, are typically such areas that Multiconsult has studied. See Chapter 10.3.4.

Large -scale solar power plants will require large areas and appear in the terrain. It will be important to develop greater solar power in good dialogue with affected communities. Experience must be gained with effects on the environment.

The technical potential for solar power on available roof and facade areas is also large, and was calculated at 65 TWh in Multiconsult's 2022 study.

NVE's cost figures for power generation show that ground -mounted solar power has lower production costs than solar power mounted on buildings, as described in Chapter 10.2. In isolation, it should indicate that larger developments of ground -mounted solar power would come earlier than solar power on buildings. The revenue side can be different for large ground -mounted plants and small facilities on buildings. Owners of large facilities sell the power in the market directly, while holders of small facilities use much of the power themselves - they are prosumers. Homeowners with solar power production can not have to pay grid and electricity taxes for the power they produce and use themselves, as long as they do not at any time deliver more than 100 kW online. Such small solar power producers have a formal status as plus customers and also do not have to pay fixed for feeding power to the grid.

RME has proposed to expand the plus customer scheme so that solar power producers are entitled to share production with other customers on the same farm and use number (RME, 2022). The scheme has been consulted. In the proposal, a threshold value of the plant's size of 500 kW is set. This scheme allows, for example, that housing cooperatives can act as plus customers, and self -produced power can be distributed between the housing units according to a fixed formula. RME has previously granted an exemption from the regulations of Powerhouse Brattøra in Trondheim to test such a micro -net solution.

If they combine solar cells and batteries, plus customers can to a greater extent cover their own consumption over the day without exceeding the power limit of 100 kW. If the price varies over the day, the batteries can also be utilized to increase the value of solar power production.

When power generation takes place behind the meter, without it being registered as production, it appears as energy efficiency. The difference is that solar power needs grid access and it affects the frequency of the network. It is in an interaction with the large

nationwide power system that is built up over time, and gradually more interconnected. It is a well-regulated system that will keep track of technical conditions, consumer rights, measurement and settlement, distribution of costs, etc.

The experience is that many are interested in investing in their own supply of power, both private individuals and industry players. Small solar power plants can also be built without a license (but often treatment is required under the Planning and Building Act), which can provide shorter lead time than for larger facilities. The high power prices from the winter of 2021/2022 have provided strong incentives to private homeowners and others who have the opportunity to install solar power, and the industry reports high activity. Solar power plants on buildings have small effects on the environment and society, and give individuals and companies the opportunity to contribute to the power supply.

There is reason to believe that solar power will be competitive in the power market within the energy commission's time horizon. It will constitute a large and important element in the power balance in the future. Today we are in a start-up phase. The regulation of the market is characterized by threshold values and exceptions that can contribute to suboptimal solutions. Local manufacturers' responsibilities and rights should be clarified, a good model for the distribution of grid costs between local solar manufacturers and other online customers must be established. Socio-economically good investment incentives should be ensured.

#### **10.6.5 Nuclear power**

In Europe, there has been a net decline in nuclear capacity in recent years, especially driven by phasing out in Germany. In other parts of the world, nuclear production increases, especially in China. Overall, there has been a flat development in the period 2005-2020 in nuclear power globally. The IEA expects growth from 415 GW today to 582 GW by 2040 (IEA, 2022).

Nuclear power provides large and stable power generation and requires little area at the production site. Technically, it is probably very favorable with more nuclear power in the European power system, all the time other thermal power generation is phased out. Among the disadvantages we find radioactive waste that needs to be handled, the consequences of accidents and the danger of spreading radioactive material that can be used in weapons.

Profitability is also uncertain, and there have been examples of expensive nuclear developments in Europe in recent years (Olkiluoto 3 in Finland and Hinkley Point C in the United Kingdom). These projects have also been characterized by long development processes and constant postponements.

The two reactors at Halden and Kjeller, which were research reactors without power generation, are both closed down and will be decommissioned (Directorate for Radiation Protection and Nuclear Safety, 2022). In the future, Norway will be without reactors in operation.

The Nuclear Energy Act of 1972 provides a framework for the development of nuclear power in Norway. However, more detailed regulations are likely to be developed if it becomes appropriate to build nuclear power plants in Norway. Without the energy commission having considered it carefully, it is obvious to assume that significant management and supervisory expertise must probably be built up, in addition to systems for waste management, if nuclear power is to be built in Norway.

#### **10.6.6 Other opportunities**

It is possible to build pure biocurrency plants, which are thermal power plants. It is also possible to combine power generation and heat production based on bioenergy. This is done



to some extent in the district heating system in Norway. Bio -power plants can have carbon capture systems. The Energy Commission is not aware of recently completed potential studies for biocurrency plants. At the same time, it is quite possible to build such power plants today, and the technology is known. Bio -power plants, often associated with district heating that improve profitability, are more widespread in Sweden and Finland than in Norway. Since it has long been possible to build biocurrency plants, it is unlikely that there is a great, unknown potential. At the same time, prospects at higher power prices can make it more relevant than before.

Bioc power plants can probably be built fairly quickly, by 2030, if there are profitable projects.

There are also several other opportunities for power generation, including wave power, geothermal energy and height wind. The Energy Commission is not aware of recent studies of the technical-economic potential for power generation based on these technologies. In the long term, however, one should be open for breakthroughs for technologies that are not relevant now.

## **10.7 heat**

Much of the energy consumption is based on electricity, but heat can be covered by different energy sources and energy carriers. About half of the electricity use in buildings goes for heat purposes, see Chapter 5. The possibilities of using power to meet the heat demand are not discussed in NVES or Statnett's long -term analyzes. In the power balance, utilization of energy carriers other than electricity will first and foremost dampen the use of power, in the same way as energy efficiency.

Chapter 5 states how the use of power per week was distributed in the five different price areas in 2021. Because a lot of electricity for heating was used, consumption was significantly higher in winter than in the summer in all price areas, see Figure 5.3. Chapter 9 shown how the power price, according to NVE's analyzes, will be affected by the scope of energy efficiency, see Figure 9.8. In particular in winter, energy efficiency is expected to help lower the price in normal and dry years. Energy -efficient heating solutions and the use of alternative heat sources will have a corresponding effect in the power system. The heat sector can permanently limit the energy and power requirements in the winter and help reduce or expose the need for investments in new network infrastructure.

The possibilities of increasing the extent of flexible heating systems are directly related to the prevalence of water -borne heat. Today, there are requirements in the Planning and Building Act that buildings with over 1000 m<sup>2</sup> of heated area should have energy-adexible heating systems that cover minimum 60 per cent of the heat demand.

### **10.7.1 District Heating**

District heating plants are flexible heating systems that allow you to use energy carriers other than electricity, such as excess heat heat, heat pumps that utilize the energy of seawater, soil or sewage and bioenergy. It is also possible to store heat energy between seasons. Different types of heat storage methods are developed in connection with district heating systems, both seasonal storage in the ground and shorter storage in thermos. The plants are flexible because they can utilize electricity when the power price is low, while other energy sources and stored energy can be used when the price is high. The flexibility of the district heating systems can be utilized both between seasons and for shorter periods of high power prices.

The district heating system in Norway is largely developed after the year 2000 with grants from Enova. In 2009, a landfill ban was introduced for waste and many district heating

systems were established in connection with new waste incineration plants. Most Norwegian cities have larger or smaller district heating systems today. District heating is not relevant in scattered areas or in detached houses, because the cost of building the infrastructure is too high.

The cost structure of the establishment of district heating systems is such that the initial costs are high, while the costs of linking an extra customer are more limited (falling average costs). In order to make a decision to invest in facilities with falling average costs, the investor must be able to believe that many customers will connect to. When NVE has granted a license for district heating in an area, it has given the municipalities the opportunity to impose new buildings connection to the plant, and this is practiced. When a liability is imposed, it follows that the buildings must be equipped with infrastructure for water -borne heat. This is further described in Box 10.7 on the district heating regulation.

### **Box 10.7 District Heating Regulation**

In 1986, the Storting adopted its own licensing law on the construction and operation of district heating systems over 10 MW (District Heating Act). An important reason for introducing such a license scheme for district heating was a desire to introduce rules on the duty of connection (Ministry of Petroleum and Energy, 1984). The obligation to attach was considered an important prerequisite to ensure the financial basis for the construction and operation of District heating system. The order for connection obligation is practiced and decided by the individual municipality, under section 27-5 of the Planning and Building Act. The duty of connection created a need for a price regulation: "The price for district heating shall not exceed the price for electric heating in the relevant supply area", cf. the District Heating Act §9.

[Box End]

In 1986, panel heaters were the relevant alternative if the heating was to be based on electricity. Today, in many cases there will be good opportunities to use effective heat pumps. The heat demand in new buildings is also more limited than in the 1980s. Questions have been raised several times whether the district heating sector is properly regulated.

On behalf of NVE, Vista Analysis (2022) has investigated a new regulatory model for pricing of district heating. NVE felt it was necessary to consider whether today's direct link between consumers' total electricity costs and the district heating price were appropriate. The problem became particularly relevant when the power price rose violently in the fall of 2021. Vista analysis shows in the report that today's price ceiling is based on an alternative source of heating that is significantly more expensive than the most relevant and affordable solution for most customers. They propose to introduce a price ceiling that is based on the socio - economic alternative cost of heating with a heat pump.

Vista also discusses the opportunities for further deregulation of the district heating sector, including free price formation. In other countries it is relatively common to have unregulated prices, but then competition authorities or consumer authorities are often involved in the district heating market. Public ownership of the facilities leads to prices being politically determined in some countries. It varies between countries if there is a duty to connect to district heating. Vista has investigated Sweden, Finland and Germany more in -depth and conclude:

"Experiences from these three countries show that it is possible to have well -functioning district heating markets without regulation of price, but that it often provides a need for different forms of market monitoring to prevent or counteract district heating companies from utilizing their position above customers."

Whether the district heating sector is properly regulated must be considered with a wider entrance than what has now been done for the price regulation. With more competition, local heating solutions will be able to compete with district heating in many cases, especially heat pumps and bioenergy. This assumes that waterborne systems are installed in the buildings, which involves a one-off cost. As there are often others who plan and finance the buildings than those who use them, a water-borne heating solution can be prioritized away, although over time it can be profitable and contribute to a more robust power system.

### **10.7.2 Bioenergy**

Norway is rich in forest resources that can be suitable for energy purposes. The harvest has increased since the 1990s, but it may be possible to further increase access to Norwegian bioenergy. These are also resources with many other areas of application, such as commodity in industry and building materials. It is primarily residual products from wood processing and demolition materials that are relevant for combustion for energy purposes on a larger scale. In addition, branches and roots from the forestry itself are an energy resource. In sewage treatment plants and reactors for biological waste, including fertilizers and food waste, biogas can be produced. Wood comes in a separate class because this is work that is taken out with wood production and often with forest clearing for the purpose. Bioenergy is an international commodity and Norway was a net importer in 2021 (4.3 TWh).

In Norway, bioenergy is used in stationary energy supply such as heat and electricity, or as fuel. Net consumption of biofuels (fired energy) was 16 TWh in 2021, around 1 TWh higher than in 2020. In 1990, net consumption of biofuels in comparison was 9.2 TWh. In Sweden, bioenergy is also used for power generation, but the profitability here is entirely dependent on the provision for surplus heat. Both the district heating systems and the industry can emit such surplus heat. In Norway, this type of thermal power generation is not widespread, but occurs in connection with waste incineration plants.

Wood burning in households amounted to 6.2 TWh in 2021. Wood firing provides flexibility in the energy system, and is widely controlled by temperature (Statistics Norway, 2021). The highest registered consumption of by Statistics Norway has registered was in 2010, which was a year of high power prices. Similarly, consumption was the lowest in 1992, a year of low power prices. The trade association for environmentally friendly fireplaces and chimneys reports high sales of stoves in 2022. Bioenergy is a flexible thermal resource that can be stored. The importance of bioenergy as a flexible energy resource in a future where the power price varies more should be analyzed more closely.

When burning bioenergy, an almost as large CO<sub>2</sub> emissions are released as when burning coal (research.no, 2019). However, bioenergy is considered climate neutral because new trees grow up again after the old ones that were carved and therefore bind about the same amount of CO<sub>2</sub>. But it can take 80-120 years from a tree in common, until a new tree has grown up completely. The critics of forest bioenergy point out that this is a very long time perspective.

### **10.7.3 The energy labeling scheme for building**

The pursuit of a good reputation is a driver in the development of the energy system of the future, see Chapter 9.7. Different branding schemes are used to show that a building or industrial activity has good energy and environmental properties.

In 2010, a duty was introduced to energy-labeled buildings to be sold or rented (Ministry of Petroleum and Energy, 2009). A grade scale was established for the buildings. The grade was based on how much the energy added to the building needed to cover a specific level of heat and electricity-specific consumption. Energy-efficient buildings, and buildings with heat pump and solar cells came high on the grade scale.

The energy carriers included in district heating production, and bioenergy, are converted into heat that are supplied with industrial companies and buildings. District heating will be added to energy even in cases where they utilize excess heat or effective heat pumps, that is, when the energy efficiency occurs in other parts of the energy system than in the end user. The use of district heating and bioenergy therefore does not represent energy efficiency in the end user, it is classified as energy consumption in the same way as electricity.

For the power system, district heating and bioenergy represent the absence of power use, and contributes to good security of supply in the same way as energy efficiency in the end user. There are particularly favorable alternatives because they reduce the need for electric heating in winter. For power security for power, the different heat resources will mean a lot in the transition we face. Such the energy labeling scheme is set up today, in some cases it provides incorrect information to the market participants about what will be good energy choices for the future. Reference is also made to the discussion of the energy labeling scheme in Chapter 9.8.2.

## **10.8 Increased pace of development**

### **10.8.1 Positive power balance requires political trade -offs**

The review of the development of energy consumption shows that there is reason to expect a growth in demand for power of between 21 and 35 TWh by 2030. Growth continues until 2050. There are opportunities to limit this consumption growth through energy efficiency, but not in the same order of magnitude as Growth in demand. Without new permits, there are no prospects for more than up to 9 TWh of new power generation by 2030, but offshore wind will make a significant contribution if it is realized around 2030. Chapter 11 discusses how the balance between demand and production can be in the future.

A key element of the Energy Commission's mandate is to propose increased power generation. The review above has shown that it is possible to expand significant amounts of new renewable energy. If it is to be expanded as much as it is needed to reach the government's climate targets for 2030 and at the same time maintain a positive power balance, difficult trade -offs must be made. There must be a much faster case with licensing authorities, overall planning is required, and framework conditions are required for all technologies that make the developments business economically profitable.

There is varying profitability and levels of conflict around the different technologies. Many mature technologies still have great potential, but are limited by social considerations and environmental reasons. Other technologies need to be helped to become market -mature, but these too will be able to meet the type of resistance that the mature technologies do today. There are supplementary energy carriers that can also contribute to a better energy and power balance, such as bioenergy and district heating.

### **10.8.2 Effective concession processing is a key factor**

The concession treatment is a central part of the total leadership time for a project that includes the entire time course from planning to concession processing and construction. There are several factors that affect the use of time in the concession treatment, including complexity and degree of conflict in each project. Other factors that affect time use are statutory process requirements, for example in the Energy Act, the Public Administration Act and regulations on impact assessments. The democratic processes and requirements for proper treatment are important to ensure a good basis for decision, local anchoring and societal cases for the measures.

In Norway, the concession treatment is largely coordinated. This basically contributes to the simplification and streamlining of the licensing process. In cases where a license is required according to various legislation, NVE coordinates the work in the reporting and application phase. For example, the treatment is coordinated under the watercourse laws and the Energy Act with the treatment under the Pollution Control Act and the Cultural Heritage Act. NVE also coordinates the case processing of larger production facilities and associated grid systems, and a joint recommendation is made to the Ministry of Petroleum and Energy in matters requiring royal resolution.

For all types of cases, guidance from the Ministry of Petroleum and Energy and NVE has been prepared for applicants and consultation parties that describe, among other things, the steps in the concession process, the different roles and what is expected of the consultation parties. Good guidance is important to avoid ambiguities and misunderstandings that can lead to loss of time. NVE has established a knowledge base on wind power in Norway on its website, a result of extensive cooperation between many state agencies. The websites will be updated and expanded over time, including guidance to the licensing process and general information on wind power in Norway.

Furthermore, NVE has prepared standardized application templates that make it easier to apply. Consultation statements can be sent digitally via an online solution, which is believed to be time -saving.

According to NVE, clear political priorities are an important prerequisite for effective licensing. An example where political management signals have been crucial to the progress of the case processing was under the so-called "small power boom" that started in the early 2000s. NVE then managed to handle a large number of cases in a relatively short time. In the period 2012-2017, according to NVE's annual reports, as many as 980 applications for small hydropower plants were processed.

### **Box 10.8 Small power boom**

In the period when the small power industry grew, there was broad political agreement to utilize more of the country's water resources in small hydropower plants. The main reasons were contributions to the necessary power generation, business development in the districts and local value creation, while the facilities were seen as not controversial and easy to realize. Based on the Ministry of Petroleum and Energy's small power strategy (2003), increased establishment of small hydropower plants was facilitated when delegating the licensing authority to NVE (from April 2004), adaptation of licensing regulations, tax adjustment and financing of R&D projects. The support scheme with electricity certificates from 2012 also contributed to more small power projects being profitable and thus applied for. A prerequisite for getting electricity certificates was that production facilities had to be built and put into operation by 2021. The deadline for the electricity certificates provided a further incentive to prioritize processing of all the small power applications that were then queued at NVE.

In order to achieve more efficient time spent in the concession treatment, NVE introduced new routines for the treatment of small power projects. Applications for small power within a geographically defined area were processed in packages instead of individually such previous practice had been. The working method was also adapted: Case managers with different professional expertise worked in teams with the individual packages. The package treatment has made it possible to conduct hearings, public meetings and inspections in parallel for several projects. It was a prerequisite that the new routines should not agree with the quality

of the assessments, but rather help to strengthen it. The package treatment has made it easier to see the cases in context, assess the overall burden and plan network connection.

The experience from this period showed that the more of the small power potential that was exploited, the more often both the technical challenges and the level of conflict increased. Towards the end of the period, the rejection percentage was more than 50 percent. There was also an increasing trend that applications were deducted before or during the case processing, and that the projects were constantly changed to increase profitability. It is part of the story that at the end of 2021 there were 279 small power plants with a granted license that was not yet built.

[Box End]

NVE has announced that growth is expected in licensing applications for larger hydropower projects in the future and that these will be high prioritized in the concession treatment because they contribute both significant power generation and flexibility to the power system. NVE will also prioritize renovation and expansion projects, because they help to utilize the hydropower potential in already developed watercourses within environmentally sound frameworks. In addition to new production, NVE will prioritize revision of terms in older hydropower licenses with the aim of modernizing the terms. Permit audits are a key tool for improving the environment in regulated watercourses, and to achieve the environmental goals of the regional water management plans prepared in accordance with the Water Regulations and the EU Water Directive.

NVE writes in a report (2020) on the licensing process for land on land that the notification phase normally takes 3-6 months from the message is being processed, while the processing of applications with an impact assessment normally takes 6-12 months. According to NVE, the detailed plan phase normally takes 3-6 months. Typical time spent in NVE for active treatment of notification, application and detailed plan is thus 1-2 years. The total leadership time will be significantly longer because one must add time for the action holder's implementation of impact assessment, preparation of application and detailed plan, as well as any complaint processing of detailed planning approval - and not least the construction phase itself.

In line with the wind power message (Meld. St. 28 (2019–2020)), new deadlines will be introduced in the treatment of wind power cases. This is to shorten the time from a message to treatment until the construction work can be initiated. In new licenses, a two-year deadline shall be granted to submit the application and the impact assessment according to the notified report program and two years to submit a detailed plan according to final license decision, and that when approval of the detailed plan, a 2-3 year is approved for 2-3 years to begin Construction. Figure 10.7 summarizes these changes, which will provide a sharp time course in future licensing treatment of wind turbines on land.

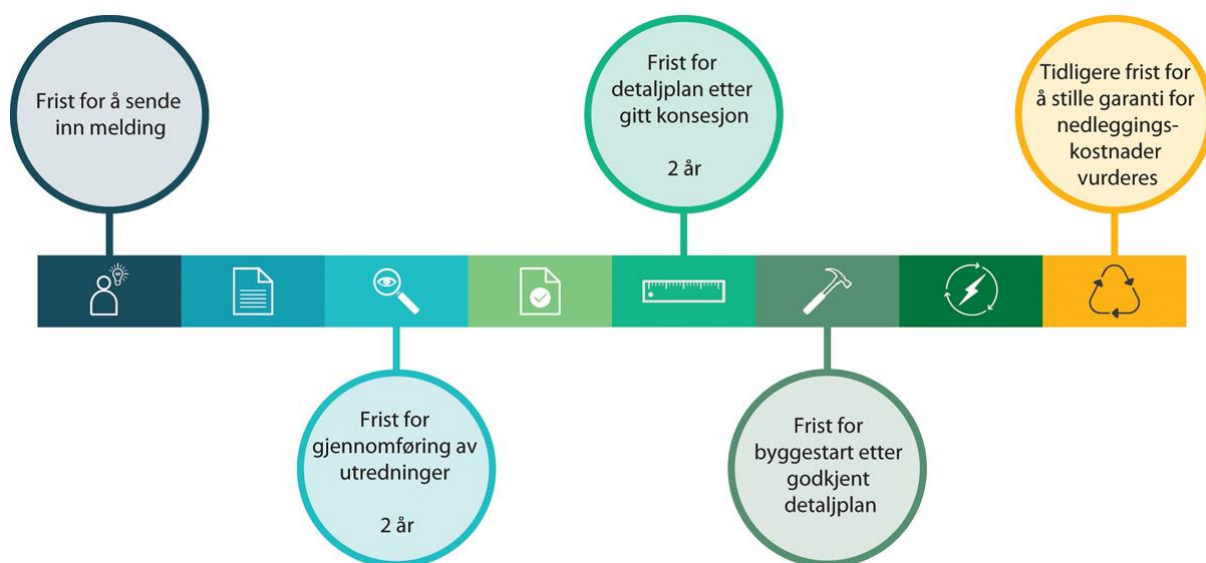


Figure 10.7 Proposal for deadlines for licensing of wind power on land Ministry of Petroleum and Energy (2020).

When it comes to offshore wind power, the proposal for a supervisor from the Ministry of Petroleum and Energy contains (Ministry of Petroleum and Energy, 2021) some deadlines in the concession processing. With today's rules, the licensing process for offshore wind, including the time the developer can spend on investigations, etc., take 8-9 years. The proposal for the supervisor is set up for shorter processing time. After the project -specific investigation program is set, the player will have two years to submit a license application, but it is opened to apply for an extended deadline. The public consultation of the application will take at least six weeks. Estimated case processing time will vary with the size and complexity of the case, but the Ministry envisions a case processing time for the license application of about one year, provided that no additional investigations must be imposed as the case processing. Time spent will increase if the decision is appealed.

The power grid selection (NOU 2022: 6) has proposed specific measures to reduce the overall lead time for grid systems. According to the committee, it is both possible and necessary to improve the processes and reduce the leadership without compromising on quality or democratic processes. The Committee points out that the challenges with lead time, uncertainty and unrestrained attachment processes are linked, and several of the measures will have an impact on more, or all, the challenges. An important example of this is digitalisation. Today, much of the work and processes that take place with both online companies and licensing authorities are characterized by lack of digitalisation. Restructuring, structuring and digitalisation of information exchange in the work on attachment process, power system assessments, concession treatment, etc. will be able to help solve the main issues associated with more efficient network development.

The power grid committee's proposal for measures also includes better information exchange, introduction of deadlines and progress plans, parallel processes, fast tracks for smaller cases and conditional construction licenses. The Committee believes it is appropriate to investigate and licensing online measures earlier, in order to reduce differences in lead time for new grid systems and lead times for the establishment of new consumption customers. It assumes that it can be probable that the measure is socially rational, possibly with conditions. The Committee is of the opinion that it is possible within the current framework to provide licenses under uncertainty based on projections, etc., and recommends that the grid

companies exploit this opportunity to a greater extent. When it comes to scheme of the queue for network connection, the committee believes that the "first come to the mill" principle should still apply. Statnett and many other network companies, for their part, believe that capacity in the network should be awarded according to a priority scheme, where one emphasizes the social benefit, and which is politically determined (Europower, 2022).

The power grid committee estimates that the time it takes from investigation to licensing and construction of, for example, larger grid systems can be reduced from 7-14 years to 6-8 years. Increased resources to the licensing authorities will be necessary to ensure that the proposed measures provide real time savings. NVE states that some of the measures proposed by the Power Network Committee to shorten the lead time for grid development has already been introduced.

NHO, KS and the Nature Conservation Association have, on behalf of the Government's top leader forum for the Sustainability Goals (2022), assessed the need for faster, better and more knowledge -based licensing processes when developing renewable energy in general. The organizations have agreed on the following measures:

1. Previous involvement.
2. Strengthen investigative capacity and competence.
3. Strengthen case processing capacity.
4. Analyzing bottlenecks and examining the use of deadlines to remove bedtime at the management.
5. Clearer priorities.
6. Prepares in conflict cases.
7. Open for parallel processes.
8. Assess different cases for simple and more complicated/disputed projects.
9. Forcing the use of digital tools and organic ground maps.
10. Preparation of industrial plots.
11. Economic incentives.
12. Innovation and technology development.
13. Faster and more transparent complaint handling.

The measures are described in more detail in a note to the Ministry of Local Government and District (the Nature Conservation Association, KS and NHO, 2022).

#### Box 10.9 Efficiency of the concession treatment in the EU

In connection with the "RepowerU" action package, the European Commission has proposed changes in the Renewable Directive, in the Energy Efficiency Directive and in the Building Energy Directive. The purpose of the amendments is to achieve faster restructuring from fossil to renewable energy production. To achieve this, the European Commission points to several bottlenecks in the administrative case processing of renewable projects that must be solved. The bottlenecks include among heavy -duty bureaucracy, a lack of transparency in the processes, little coordinated legislation, unclear roles and Lack of guidance to the actors.

The European Commission proposes a simplified and more coordinated system for streamlining the concession treatment of renewable energy projects. The proposal includes all administrative permits to build and operate both production facilities, energy storage facilities



and grid systems. The case to be simplified applies from an application to be received until there is a license decision.

The proposal means that Member States must create predefined "go-to areas" both on land and in sea areas where there are natural conditions for renewable energy, for example for wind and sun. The designation can take place through a total or more separate planning processes. The processes should be in line with the SEA Directive (Directive 2001/42/EC, on strategic impact assessments), and should be so extensive that one should, as a general rule, release an impact assessment process in the next half. However, an impact assessment may be necessary if significant and unforeseen environmental effects that cannot be mitigated are likely to occur.

The "go-to areas" should together be so large that they ensure that each member states reach their renewable target. In such zones, the concession treatment for smaller projects cannot exceed six months. Total time spent on licensing of major renewable energy projects within the predefined zones will be one year. In extraordinary circumstances, the time frame can be extended by up to three months. Applications regarding the establishment of renewable projects outside the predefined zones will have a treatment time of two years. For these projects, an extended treatment deadline of up to three months can also be given. Any complaint processing comes in addition to the deadlines set for the concession treatment.

In order to streamline the case processing, the member states must create one or more contact points with the licensing authority. The contact points shall provide the necessary guidance and ensure that the licensing process is coordinated with other relevant authorities and actors. The contact points will also be responsible for complying with the schedule. Simple procedures will be established to handle disagreements and disputes that may arise in the licensing process.

[Box End]

## **11 power balance and prices towards 2050**

The power balance is a measure of whether an area has excess or deficit of power. The Norwegian power balance is given by the country's overall production ability this year with normal rainfall and consumption of power. However, there are large variations in the observed power balance from year to year. In Norway, this is largely due to variations in rainfall and thus inflow to the water reservoirs. A country with a positive power balance will normally be the net exporter of power, while the opposite is the case for a country with a negative power balance.

The power balance can say something about security of supply and the relative price level compared to the surrounding areas. Security of supply will also depend on the exchange of power with other countries and the supply situation there. A positive power balance indicates a lower price level than in surrounding countries, but periods of higher prices may occur. Also, negative power balance does not in all situations higher prices than in the surrounding countries. This chapter discusses possible development in power prices and the power balance until 2050.

The long -term development of the Norwegian energy system is regularly analyzed by several environments, including by NVE and Statnett. Long -term analyzes of the power market and energy markets are based on a number of assumptions with great uncertainty. Power market models are tools that can provide information on how different drivers in the power system and market collaborate. Based on this, it can be estimated in power prices. In this chapter, NVE and Statnett's latest long -term power market analyzes are the main basis for the assessments (NVE, 2021) (Statnett, 2020). We primarily describe the development abroad

together, and thus do not distinguish between developments in our Nordic neighboring countries and the rest of Northern Europe. However, Norway has strong network connections to our Nordic neighbors, and development in production, consumption and power grids in the Nordic countries will have a strong impact on Norwegian prices. In addition, as these analyzes came before the war in Ukraine, the Commission has supplemented with assessments from other analysis environments that can shed light on some consequences of the current situation for the energy sector. However, there is great uncertainty about this.

The prerequisites for model driving are important for the results. A significant difference between NVE and Statnett's analyzes is that Statnett assumes that the entire European energy sector will be emission -free until 2050, while NVE is based on existing and well -known new tools. However, these instruments are not expected to be sufficient to reach the climate goals.

The long -term power market analyzes seek to capture effects in the power market. However, the general economic development in society also affects plans for power consumption and power generation, and vice versa. The long -term power market analyzes do not model the interaction with the economy as a whole. This means that significant counters and effects can be poorly represented in the analyzes. An example is how supply and demand for various input factors interact.

The long -term analyzes of development in use and production of power have been reviewed in Chapters 9 and 10.

## **11.1 Trends**

The future power balance and power prices in Norway will depend on several factors. We call them drivers for developments in the Norwegian power market.

On behalf of the Energy Commission, Multiconsult Norge AS and The Thema Consulting Group have prepared a report on drivers and uncertainty in long -term energy market analyzes (Multiconsult and Thema, 2022). They find broad agreement among the analysis environments on drivers and uncertainties for the energy sector.

In the review of important drivers, there is a separation between production, consumption, storage and consumer flexibility, fuel prices and CO2 prices. The findings are summarized in Figure 11.1. The table on the left shows the most important drivers. These have different degrees of importance and uncertainty, which are illustrated on the right in the figure. The horizontal axis indicates how important the players believe a driver is, while the vertical axis indicates the uncertainty associated with the same driver. The arrows indicate how the analysis environments consider that uncertainty and importance for the various drivers develop from 2030 to 2050. The drivers are discussed more closely below.

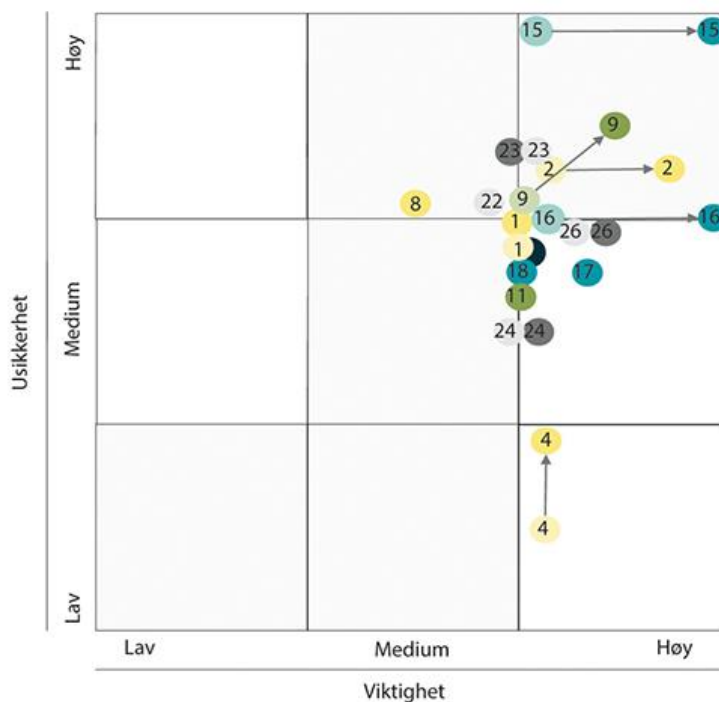
### Viktigste og mest usikre drivere

**Produksjon (kapasitet&kostnad)**  
 1. Landbasert vindkraft  
 2. Havbasert vindkraft  
 4. Vannkraft  
 8. Kjernekraft

**Forbruk**  
 9. Industri  
 11. Transport

**Lagring/forbruksfleksibilitet**  
 15. Hydrogen  
 16. Forbruksfleksibilitet  
 Infrastruktur  
 17. Mellomlandsforbindelser  
 18. Internt Norge

**Brensels- og CO<sub>2</sub>-priser**  
 22. Gasspris  
 23. CO<sub>2</sub>-pris  
 Politikk og regulering  
 24. EU-mål (utslipp, fornybarproduksjon, energieffektivitet)  
 25. Norske mål  
 26. Subsidiert/støttesystemer



- Mot 2030
- Mot 2030
- Mot 2030
- Mot 2030
- Fra 2030 og mot 2050
- Fra 2030 og mot 2050
- Fra 2030 og mot 2050
- Fra 2030 og mot 2050

Figure 11.1 Important drivers and associated uncertainties in long-term analyzes Multiconsult and Thema (2022).

#### 11.1.1 More renewable power provides greater price variations

The facility on European and national climate policy and technology development will have the clear most important impact on changes in the power market by 2050, according to the analysis environments Multiconsult and Thema interviewed. The climate position means that fossil energy sources should be replaced with renewable power. The restructuring is created, among other things, through pricing of greenhouse gas emissions, requirements for electrification and measures to stimulate increased renewable power generation. The analysis environments believe that there is great uncertainty about developments in gas and CO<sub>2</sub> prices in the future, while also being important drivers for development.

Developments in Europe and the Nordic countries are crucial to understanding price developments in Norway. The transfer capacity internally in the Nordic countries is large, and there is significant transfer capacity between the Nordic countries and Northern Europe. Norway will receive increased price variation when the countries we trade with get a more weather-dependent power generation. The fact that we have the opportunity to magazine water can dampen the price fluctuations domestically. Hydropower manufacturers can take into account that there will be periods of low production of wind and solar power, and other periods of high power generation. Decisions on magazine disposal are made under uncertainty, among other things about future prices, see Chapter 3 on SINTEF's analyzes of magazine disposal in the fall of 2021.

#### 11.1.2 Production

The development of new production capacity depends on political decisions, including permits for development and clarity in framework conditions. In addition, the analysis environments point out that the power price and technology development will be decisive for how much is being built, both for water, solar and wind power. After 2030, wind power is expected to account for the largest production growth in Norway.

At the same time, there is uncertainty about the development of wind power both on land and at sea. For land-based wind power, the uncertainty is particularly related to concession policy and social and political acceptance. For sea power generation, uncertainty is linked to framework conditions, technology and cost development and web solutions, such as attachment countries and points.

Hydropower plays a crucial role in the Norwegian power system, but is also important in the Nordic and European contexts. Hydropower is expected to become an even more important source of flexibility in the future, when unregulated power from wind and sun is a larger proportion of production.

### **11.1.3 Consumption**

It is agreed that the demand for power will increase in the years to come. It is the assessments of power demand in the industry that vary most in the analyzes. Any industrial establishment will seize important resources, thus reducing the possibilities of establishing further industry that need the same input factors.

Access to renewable and relatively affordable power is an advantage in Norway. Everything else equal gives a higher surplus of power lower power prices. The advantage with low power prices compared to the countries around us will be weakened for each industrial establishment, and strengthened by investments in power generation and energy efficiency. Different types of industry emphasize the power price differently, and there are several factors that affect whether they establish themselves in Norway, and in particular the possibilities for grid connection (Oslo Economics, 2022), see Chapter 9.

The analysis environments expect the existing industry to carbonize and increase power consumption to a large extent, either directly when restructuring to electricity or indirectly through the use of hydrogen or carbon capture.

### **11.1.4 Storage and flexibility**

Norway has always balanced the power system with hydropower magazines. In the future, Batteries and hydrogen could play an important role in balancing the system. The consumption's adaptation to production will be a very important contribution to the power balance. In addition, technologies that can store energy when the power price is low will be able to return in the energy system during periods of low renewable production and high prices.

By 2050, a larger part of consumption will be expected to be flexible. New technology and automation enables and simplifies the relocation of consumption in time. At the same time, several new consumption categories will be flexible because it will be profitable to adapt to the power price, either by utilizing low power prices or by avoiding the highest prices.

## **11.2 Power Balance**

There are large variations in the power balance from year to year. Consumption varies with temperatures and power generation varies with inflow and wind conditions. Investments on the production side and development on the consumption side are of great importance for the power balance. Norway is currently a net exporter of power in normal years. Figure 11.2

shows the development in the power balance from 1990 to 2020. The dark gray line shows temperature -corrected consumption, while the Norwegian production ability in a normal year is shown in blue, gray and green. The Norwegian power balance is the difference between these. The power surplus fell in Norway from 1990 to the 2000s. In Wind and heat power vests contributed to a significant power surplus later, despite the increase in consumption. In 2021, the power surplus was about 20 TWh.

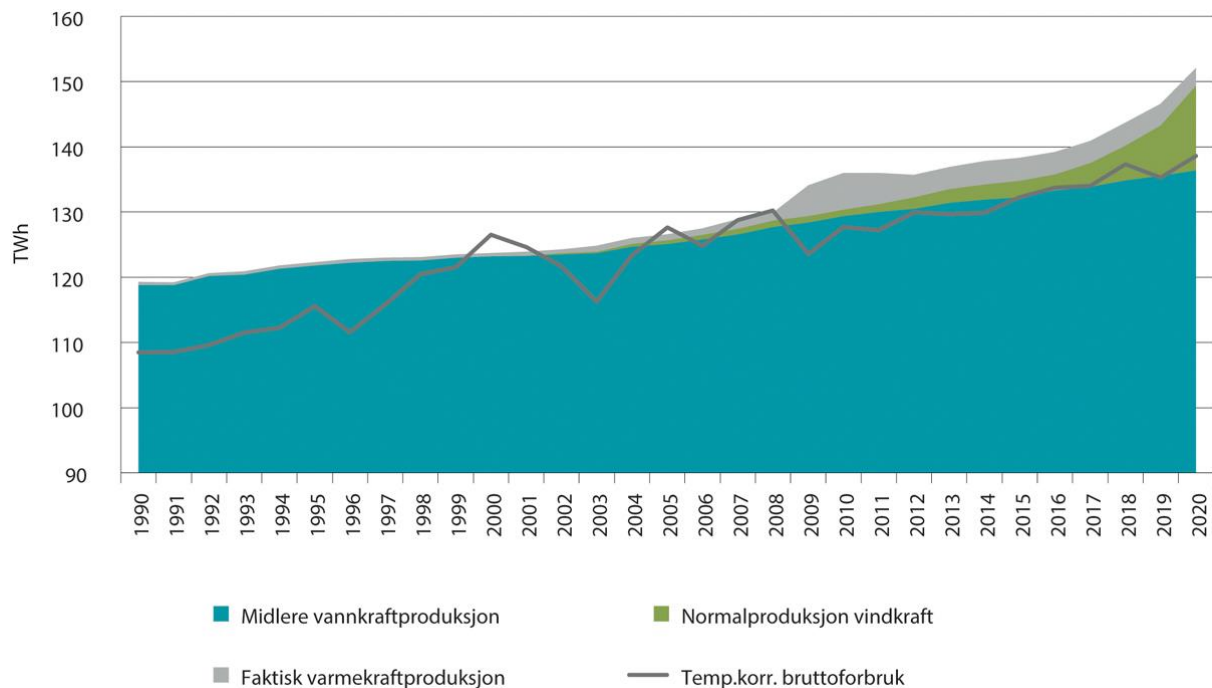


Figure 11.2 Production ability and temperature-corrected consumption 1990-2020, TWh/year Energy power Norway (2022).

In the short term, a positive power balance will mean that we have a surplus of power that must be exported. In the long term, a surplus of power domestically can be eaten in whole or in part by increased consumption at home, which in turn weakens the power balance.

### 11.2.1 The power balance becomes tighter

In its 2021 analysis, NVE expected power consumption up to 2030 would increase more than power generation, and that Norway would thus have a tighter power balance. This assessment was divided by Statnett (2021) and Multiconsult and Thema (2022). In Statnett's last short-term market analysis, Norway is estimated to have a negative power balance in 2027 (Statnett, 2022). Without new production, the deficit can be even greater if consumption is not reduced due to higher prices in Norway than in our neighboring countries. Statnett expects the situation to turn to a surplus on the power balance as significantly more power generation comes in further ahead.

To the left in Figure 11.3, NVE's estimates for development in production and consumption are shown in the latest power market analysis. In its basic alternative, NVE expected the power balance to be tighter until 2030, with 7 TWh power surplus in a normal year. From 2030 to 2040, they have assumed a somewhat higher growth in power generation than in consumption, so that the power balance in Norway is strengthened somewhat.

To the right in Figure 11.3, the power balance is shown from 2021 to 2030 in NVE's analysis of the relationship between power balance and power price from August 2022, for three

different scenarios. The scenarios are high and low scenario in their analysis of power balance and prices from August 2022, while the basic scenario is from NVE's long-term market analysis from 2021. High scenario gives a power surplus of 19 TWh in 2030. In the scenario is due to the high profits of a lot of ocean wind. Consumption growth and more energy efficiency than in the base scenario. The low scenario provides a negative power balance of 5 TWh. The low scenario power deficit follows from 12 TWh higher consumption growth than in the base scenario. Consumption growth in the low scenario comes in light industry, data centers and hydrogen. Less energy efficiency is also used in buildings.

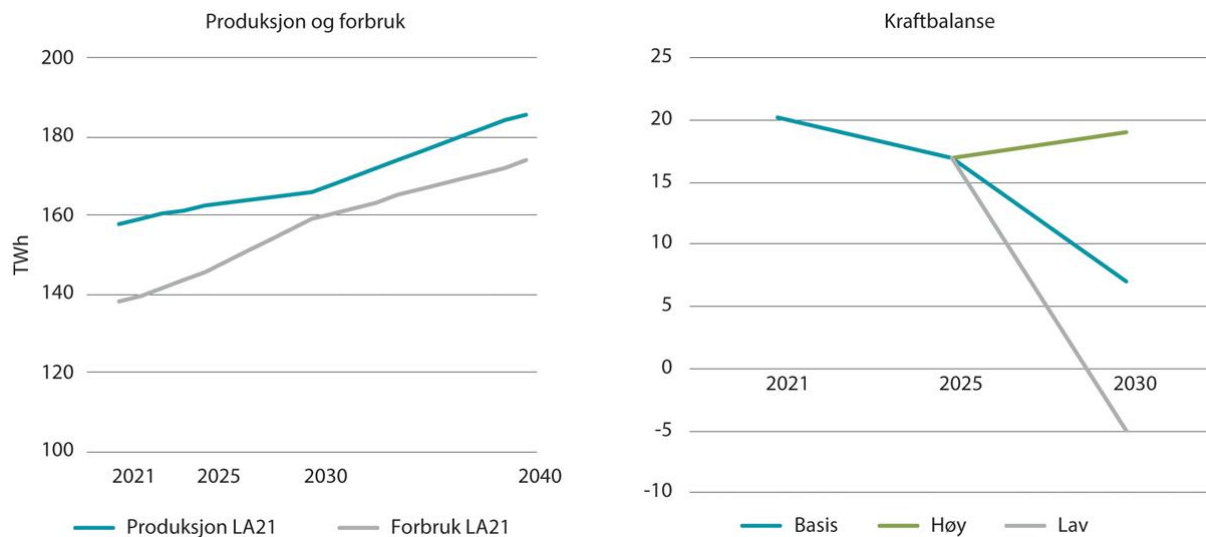


Figure 11.3 NVE Estimates for development in production and consumption in Norway 2021-2040, and power balance 2021-2030 in base, high and low scenario, TWh/year NVE (2021) and NVE (2022).

### 11.2.2 Inequalities in projections of the power balance

A comparison of NVES and Statnett's analysis can provide insight into how the power balance is affected by some assumptions. There are many differences in the model equipment and in the assumptions for the calculations. Therefore, a comparison cannot be used for precise conclusions.

NVE's long-term market analysis from 2021 used existing and adopted climate policy and well-known instruments. Statnett's analysis used net zero emissions in 2050. For Norwegian industrial consumption, both NVE and Statnett use well-known plans, but with an adjustment for what they think is realistic. Statnett prescribes a higher and faster growth in consumption than NVE. In retrospect, the Environment Directorate (2022) has published a partial analysis with measures that will cut greenhouse gas emissions in the quota sector with 67 per cent beyond the current obligations. This analysis draws in the direction of an even higher power requirement than NVE and Statnett have calculated, see discussion in Chapter 9.

Both NVE and Statnett find that there will be a surplus of power in 2030, but on various premises, including on climate policy and power development. Normal year production is calculated by NVE to approximately 157 TWh in 2022, see Chapter 5. In Statnett's analysis, increased power generation of about 18 TWh is expected in 2030, while NVE's analysis provides increased production of about 9 TWh. It is wind power production that makes the greatest difference between Nves and Statnett's analyzes towards 2030. In Chapter 10, it is pointed out that with today's given licenses it may be possible to build new power plants that

provide about 9 TWh of power generation by 2030. This includes water and water and Wind power.

In order to maintain today's power balance, according to both NVE and Statnett, there will be a need for significantly more production than licenses have been granted today, and significantly more energy efficiency than what they have included in the analyzes.

Figure 11.4 shows historical development of the power balance and the projections in NVE and Statnett's analyzes. We see that power consumption is rising. Statnett also expects an increase in production that is higher than we have seen historically.

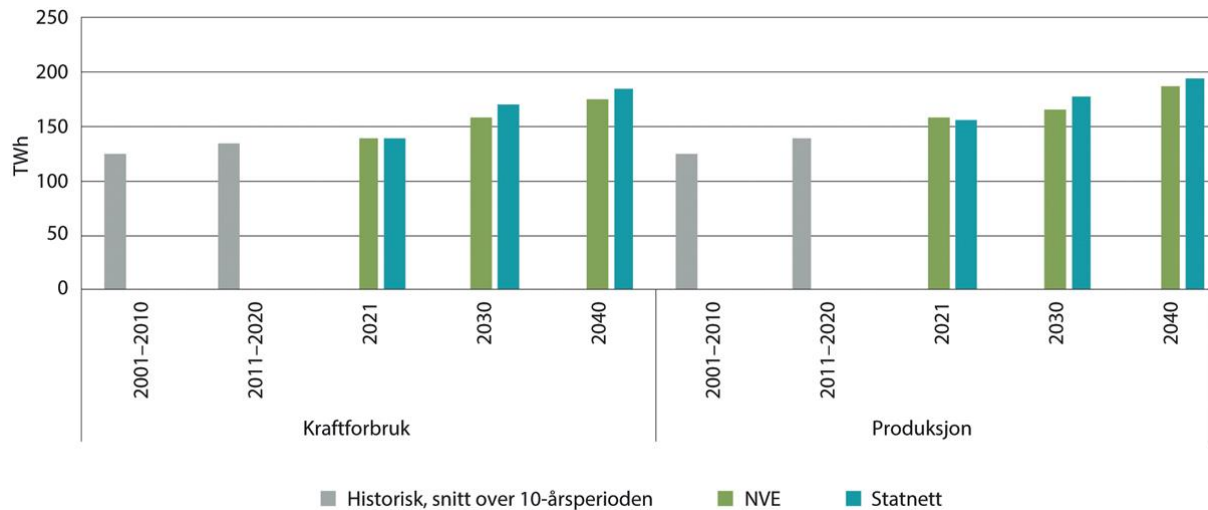


Figure 11.4 Power consumption and production, historically and in Nves and Statnett's long - term power market analyzes, TWh/year

NVE (2021) and Statnett (2021).

### 11.2.3 power exchange in dry year and wet year

The biggest challenge associated with the power balance in the Norwegian power system is the large variations in the inflow of water between years. Although we have a large surplus of power in normal years, imports may be needed for dry years. Transfer capacity abroad reduces the dry year challenge. A large surplus of power will make us less vulnerable in dry years than if the power balance is tight.

Simulations made in the Thema's power market model show that a power surplus in Norway of approximately 7 TWh in 2030 can be expected in 2030 in a year of average weather (Thema and Multiconsult, 2022). This profit will be exported. However, the expected exchange with abroad varies widely. In extreme dry years there will be a large power deficit in Norway. If production capacity and demand for power develops as in THEA's projections, weather conditions that in the cold and dry year 2010 will provide a power deficit on the order of 35 TWh in 2030.

To illustrate the situation in a cold and dry year, Thema has simulated 2030, but with consumption that in the cold year 2010. Figure 11.5 shows consumption throughout the year in 2030, based on the low temperatures in 2010, illustrated with the solid line. The colored fields show the production given that we will have a dry year as in 2010. Norway will have net imports every week in this scenario.

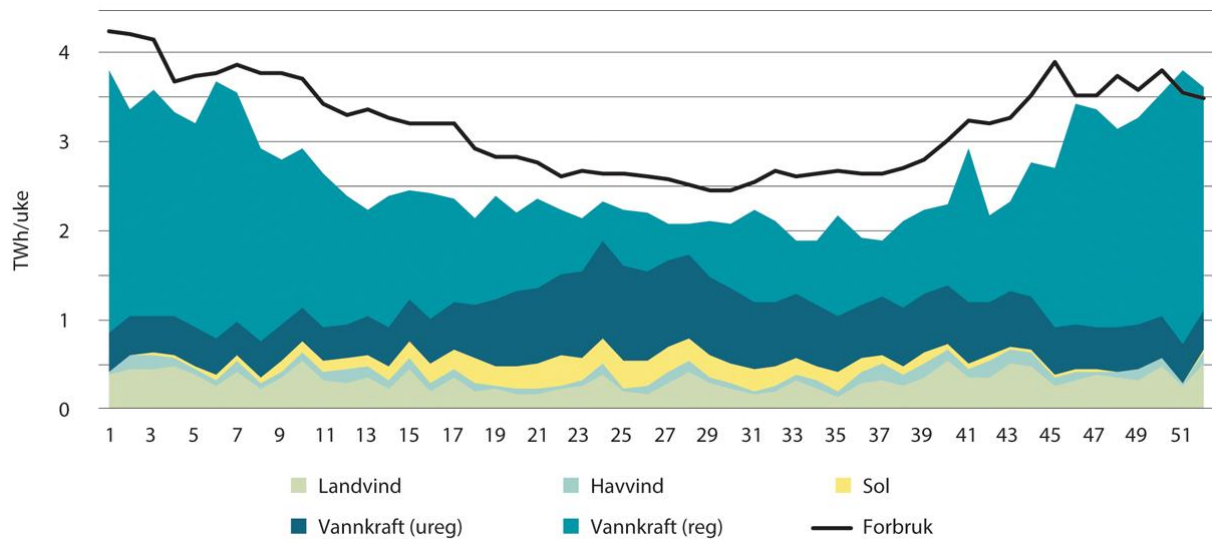


Figure 11.5 Power consumption and renewable production in a cold and dry Norway in 2030, TWh/week

Thema and Multiconsult (2022).

Figure 11.6 shows Thema's simulation of power exchange in 2030 with weather conditions such as in the dry year 2010, hour by hour. The maximum import capacity of 9 GW is utilized in the simulation for more than 1200 hours. There are also exports for a few hours. Norway will import approximately 1 TWh per week during the buttonest periods

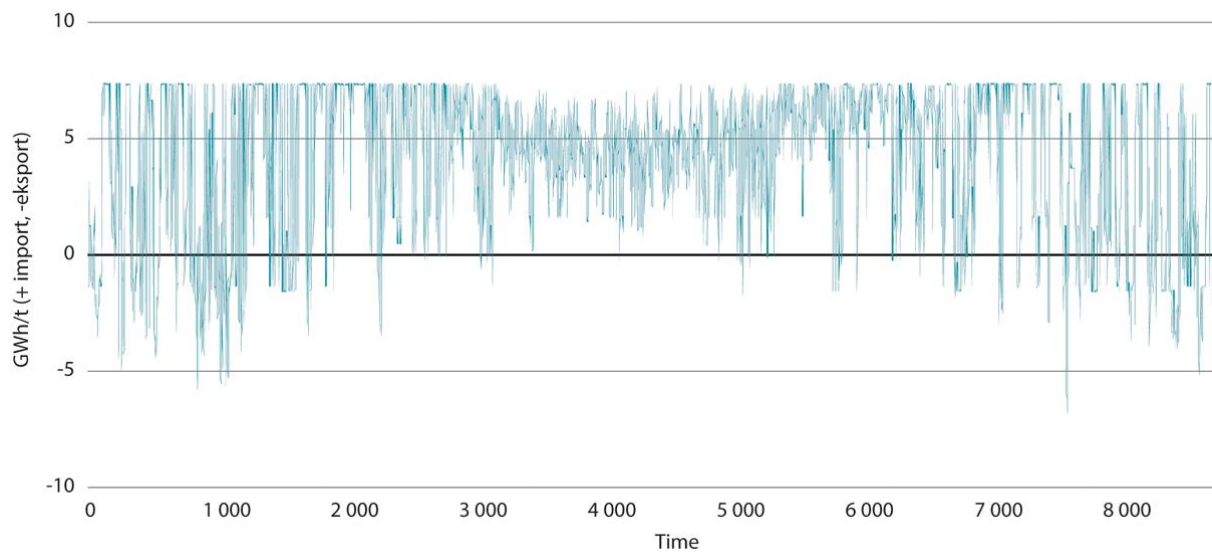


Figure 11.6 Import and export of power in a dry year hour by hour, GWh/H

Thema and Multiconsult (2022).

The energy challenges in such a dry year typically occur a few weeks in March and April. Import capacity is too small to meet the entire demand and it is necessary to have reserves in the spring. According to Thema's analysis, we must have 6.5 TWh of power available in the spring bundle, in the form of magazine force and consumable flexibility, to avoid rationing. In 2010, 16 TWh of power was produced by using water stored from previous years. Imports throughout the year mean that water is saved that can be utilized on the tamp of the tapping



season. Historically, Norwegian magazine fill levels have never come lower than about 16 TWh.

In a dry year, high prices must also be expected to the end users. The experience from the winter of 2021/2022 is that the consumer response can be important in a situation with high prices. This is discussed in more detail in Chapter 9. Consumer response is not included in the THEMA analysis, so the deficit will in reality be lower than 35 TWh.

In the simulations, the maximum import capacity in a normal year is only used 120 hours, and in a wet year it is never used. The hours of imports are distributed throughout the year, and in all weeks there are both hours of export and hours of import.

Figure 11.7 shows the historical inflow from 2000 to 2021 and Thema's forecast for developments in the future in normal years, dry years and wet years. The figure illustrates that the difference between the inflow in wet and dry years is expected to be greater in the future. The foreign connections give us opportunities to utilize water resources well for wet years by exporting the profits. With a large surplus of power, we get to use less of what comes from extra water in wet years, because much of the export capacity is seized by ordinary production.

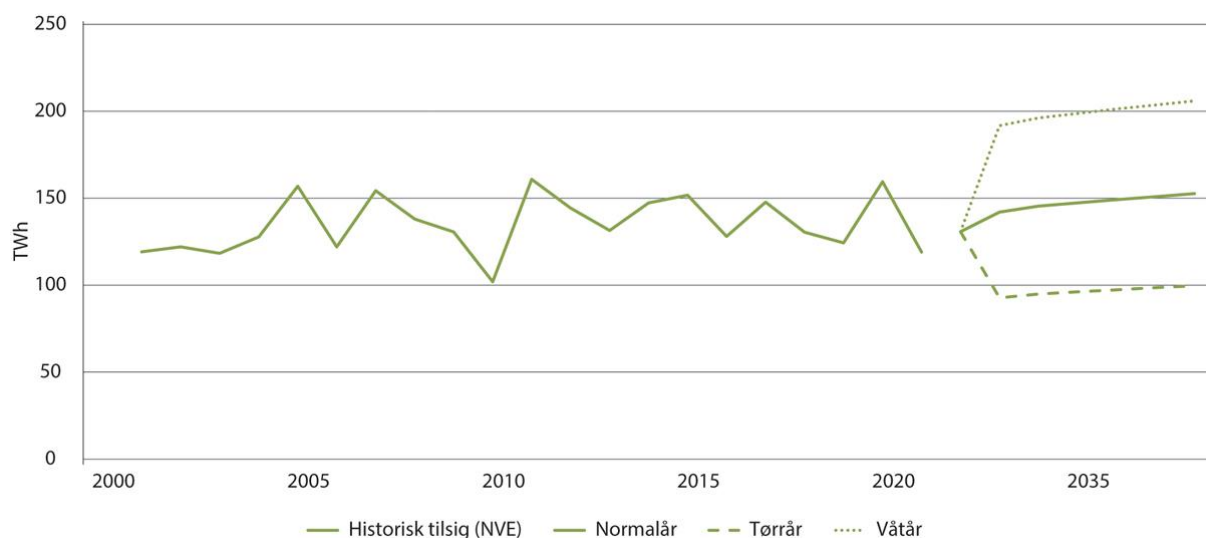


Figure 11.7 Historical inflow and forecasts of inflow in normal years, wet years and dry years, TWh

Thema and Multiconsult (2022).

This year with high magazine filling, the value of the water is low. Power is still produced, otherwise there is a risk that the magazines will run over and that the water will be lost. In such situations, the power producers cannot save the water at a time when the power price is high. The water value is thus lower than when we are in an import situation and the price is determined by the cost of coal and gas power. Fuel and CO2 prices have less impact on water values and Norwegian power prices in situations with high magazine filling.

In the future, a warmer and wetter climate will increase the total water gap in Norway. The increase in inflow will be greatest in winter, while the inflow in the summer is reduced due to less snow and glacial melting. Most of the increase in inflow can be utilized for hydropower production (NVE, 2019). However, there may be major regional differences.

### 11.3 Prices and Price Variation

The water value plays a central role in the price level, and it is affected by the price outlook in Europe, but also by the power balance. When there is much unregulated power generation in Norway, prices can be significantly lower in Norway than in Europe. The export capacity is then fully utilized. Similarly, we may have higher prices than the areas around us in dry years when we are in great need of imports. In single hours with very low or very high prices in the areas around us, flexible hydropower contributes to the utilization capacity being fully utilized and we get less price variations than the markets around us. By 2040 and 2050, the water values will continue to play a key role in price formation in Norway.

In a study of over 43 scenarios in 15 different Nordic power market analyzes, Chen shows one. eel. That the price level for power in the Nordic countries is expected to be strongly correlated with the costs of gas power production (gas such as fuel and CO2 costs), (Chen, Hexeberg, Rosendahl & Bolkesjø, 2021). Over time, the price in Norway will thus depend on consumption growth, production capacity, fuel prices, CO2 prices and exchange capacity. Prices, on the other hand, will vary with rainfall, temperature and wind and sun conditions during individual periods. During periods of a lot of wind and solar power production, the price will be low.

#### 11.3.1 Price level in Norway

NVE estimated in its long -term power market analysis from 2021 that the prices until 2040 will be significantly higher than the average in the previous 20 years. The reason for this was that they envisaged higher CO2 prices and an increase in the exchange capacity between Sweden and Germany, and between Denmark and the United Kingdom. Figure 11.8 shows the left historical, annual average prices in Norway (gray line). To the right, the figure shows the average Norwegian power price from 2025 to 2040. The solid line is NVE's basic scenario in the analysis in 2021 and the dotted line is from the analysis in 2020. The outcome space around the basic path (shaded field) follows of different assumptions about fuel and CO Prices. All prices are in NOK 2021.

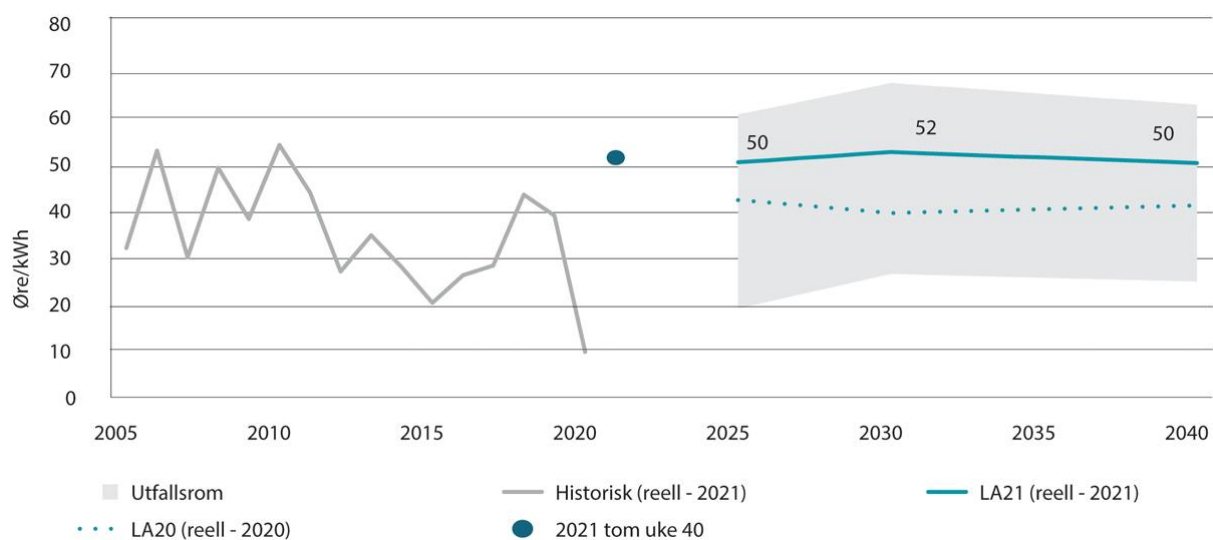


Figure 11.8 Historical and estimated future power prices, øre/kWh NVE (2021).

Towards 2030, NVE expected prices in the range of 45-55 øre/kWh in Norway, with an outcome room of 20-30 per cent. Prices in Northern Norway were expected to be lower,

prices in central Norway in the middle and southern Norway highest. Towards 2040, NVE expected the level to be somewhat lower in southern Norway, just in excess of 50 øre/kWh. Developments in the gas and CO2 prices were expected to be central to price developments in the years leading up to 2030, while towards 2040 there is the development in hydrogen, batteries and switch-off prices for consumption that is most important.

Both NVE and Statnett have lower average prices in Northern Norway than in southern Norway in their analyzes, and reduced differences towards 2040. This is because the net capacity north-south in Norway and Sweden is not high enough to equalize the prices. In the past year, price differences between the north and south have been significantly greater than we have experienced in the past, see Figure 11.9. NVE writes that "if the price level of the continent and the UK increases, the price differences between the north and south in Norway in Norway will be greater". NVE and Statnett's analyzes of the price differences were based on a normal situation, not today's extreme situation.

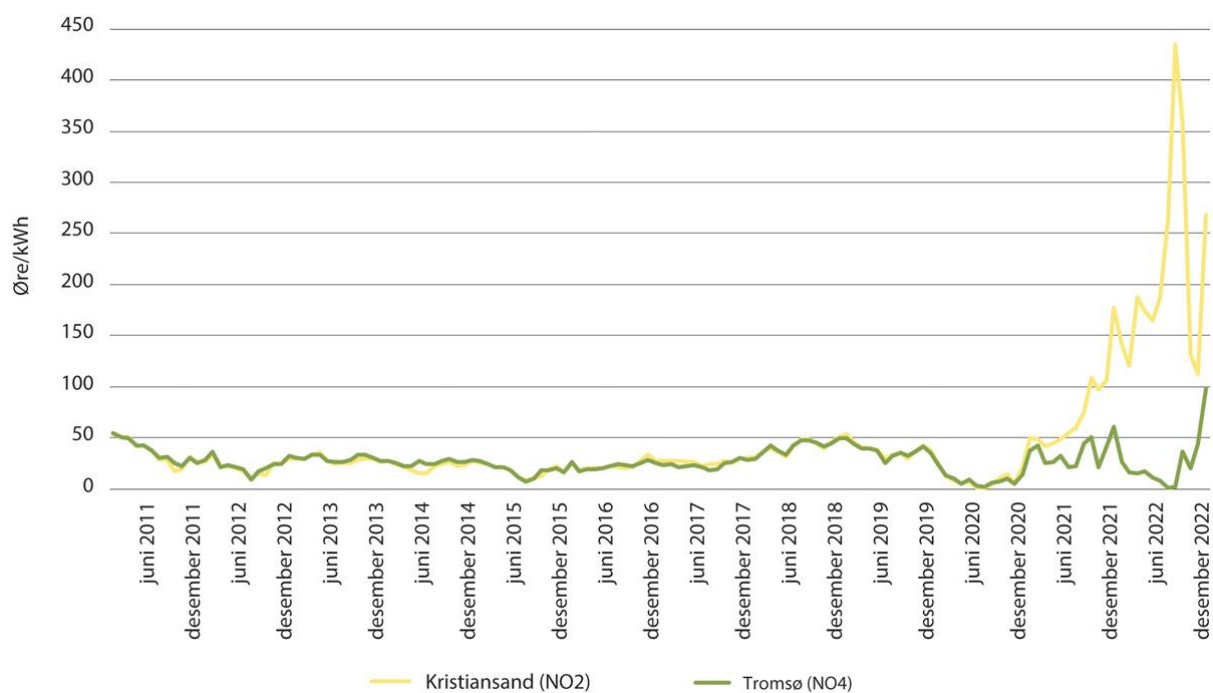


Figure 11.9 spot price in NO2 (Southern Norway) and NO4 (Northern Norway) 2011- 2022, øre/kWh

Nord Pool (2022).

Although no specific analyzes have been done, it must be assumed that the bottlenecks in the network mean that the price differences between the north and the south will be large in a time to come if today's gas and power prices in Europe persist. Over time, the development of the regional power balance and grid capacity will affect area prices. The situation in Sweden also affects the price differences in Norway. The Swedish network has significantly higher capacity north-south than the Norwegian. Both the Norwegian and Swedish networks are thus used to transport power between the regions in Norway. Developments in Swedish regional power balances are therefore also important for price developments in Northern Norway. There are big plans for industrial establishment in the north, both on the Swedish and Norwegian side. At the same time, there are good wind resources that can be utilized, which can be expanded on both sides of the border.

The high prices in Europe today are primarily related to high gas prices as a result of Russian gas being largely gone from the market. It raises questions about the transition from the current situation to a new normal, see Box 11.1.

### 11.3.2 Norway gets a lower price level than Europe

Both Statnett's and NVE analyzes showed that the price in the Nordic countries would be at an average of a lower price level than in Europe, both in 2030 and 2040. In Figure 11.10, the power price in the Nordic countries, the UK, Germany and the Netherlands are shown for the period 2010 to 2020, and NVE's simulations of future prices in the same countries.

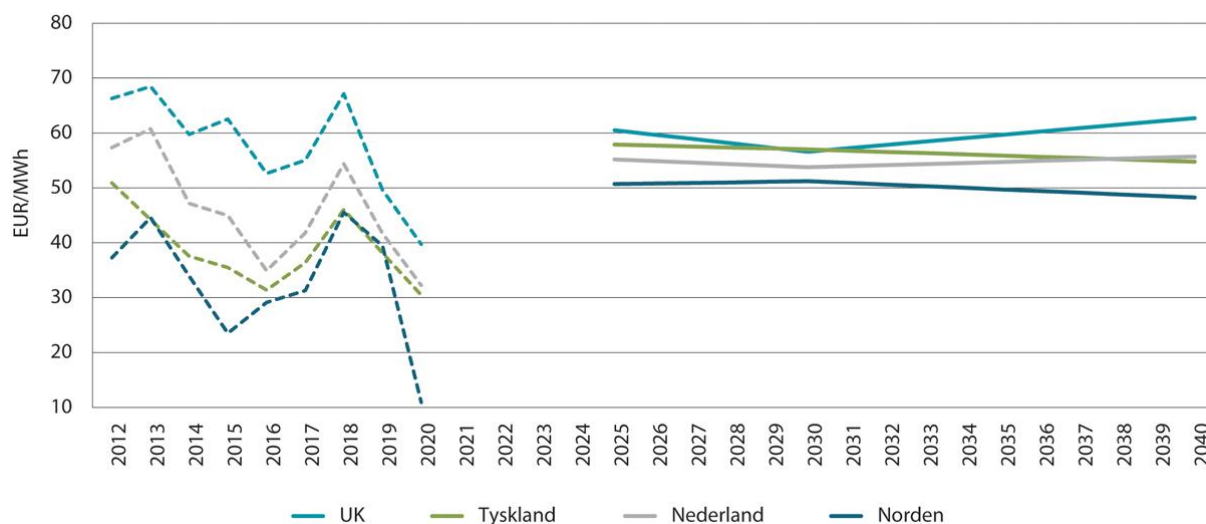


Figure 11.10 Historical and simulated average power prices in the UK, Germany, the Netherlands and the Nordic countries, 1 Euro/MWh, 2021 prices

1 Historical power prices even Week 35 in 2021.

NVE (2021).

Although on average, the power price is expected to be lower in the Nordic countries than in the countries we trade with, it is expected that situations will also arise where the price in the Nordic countries will be higher. Wind and solar power production has a lower useful life than many of the production technologies that are in today's system. In order to ensure some production during periods of low wind and sun, the increase in the installed performance in Europe will increase more than the energy production will increase. During periods of good wind or sun conditions, production will be very high and prices will be low. In high production situations, Europe can get lower prices than Norway, and it will happen more often than before. During periods of poor wind and sun conditions, expensive technologies must be used, and the price in Europe can then be higher than in Norway. We must also expect that prices in the Nordic countries will still be affected by inflow to the water reservoirs, and that they may be higher than in Europe in dry years.

### 11.3.3 Larger price variation in Norway

In Norway, prices have traditionally varied with outdoor temperature and inflow to the hydropower plants. The big transition to more wind and solar power in Europe and expectations of higher CO2 and fuel prices mean that both Statnett and NVE expect greater variations in the power price going forward. Fossil power generation is expected to be phased out towards 2040, but will still be able to set the price during periods of little wind. Figure 11.11 illustrates NVE's simulations of price variation in the years to come.

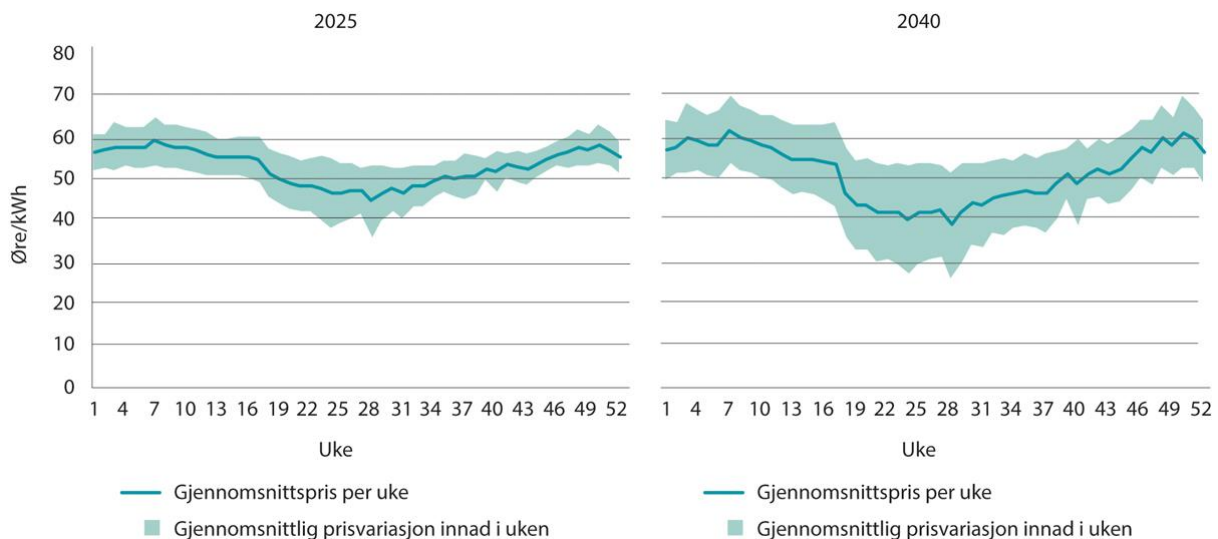


Figure 11.11 Simulated average power price and price variation per week in southern Norway (NO2) for 30 different years, in 2025 (left) and 2040 (right), øre/kWh

NVE (2020).

To the left of the figure, the seasonal variations are shown in 2025, and on the right the variations appear in 2040. The solid line shows weekly power prices, while the outcome room around the line shows the expected average price variation for 30 weather. The outcome room does not describe extreme cases, such as zero prices in single hours in the summer. That's because the figure shows the average weekly variation. NVE's simulations show that power prices in the future will vary more from day to day, from season to season and from year to year. The price will be highest and the price variation greatest in winter.

In its analysis, Statnett points out that the variations in power prices will be different for different groups. The industry can achieve lower prices than the average prices, by adjusting consumption during periods of particularly high prices. Households, which have greater consumption in the winter than in the summer, are expected to face higher prices than the average price over the year. Hydropower manufacturers with magazines will achieve a higher price than manufacturers with low storage ability. In Statnett's analysis, solar power and river power will achieve almost half of the prices as the magazine power plants towards 2040. Wind power achieves higher prices than solar power and river power, and offshore winds achieve somewhat lower prices than wind turbines on land, see also Chapter 10.2.2.

### Box 11.1 The transition to a more normal situation

Russia's invasion of Ukraine with subsequent high energy prices in Europe has created uncertainty about energy prices in Europe. There are several factors that will affect energy prices in the next decade. Global gas prices and Europe's access to gas are among the most important. In the European power market, gas power plays a central role. As gas power is often the marginal production technology, the gas price plays a significant role in the European power price. The gas price is partly set in a global market and is influenced by the costs associated with extracting and transporting gas and expectations of future inventory and gas consumption. Normally, Europe has received large parts of its gas delivered through pipes from Russia and Norway. After the war in Ukraine started, Russian gas has gradually received a lower share in European gas supply.

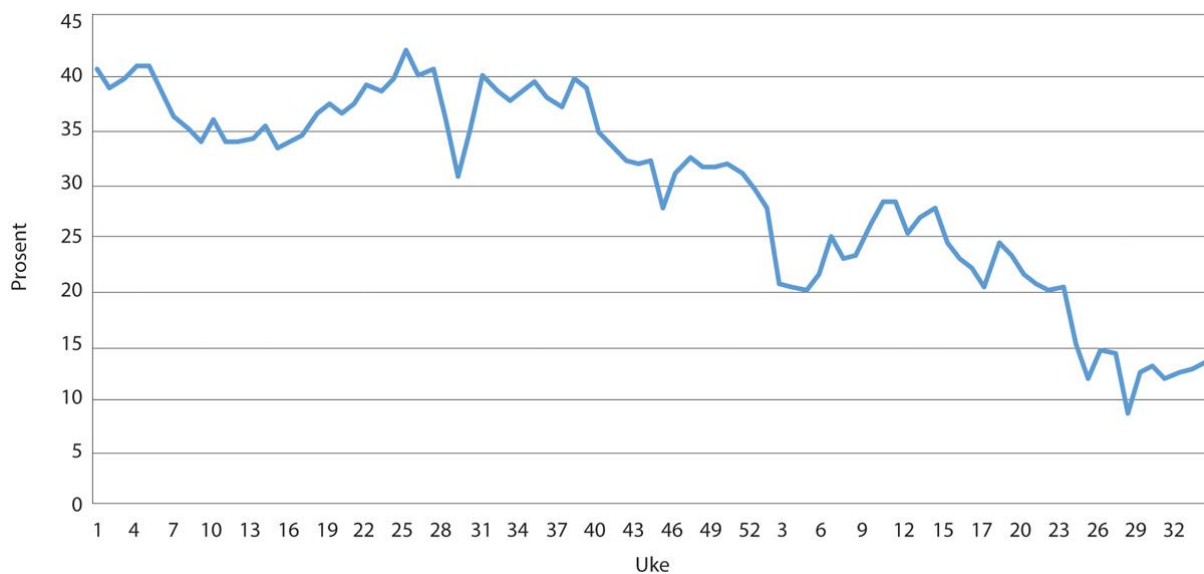


Figure 11.12 Russian share of European gas imports 2021–2022

Bruegel and ENTSO-G (2022)

As the Russian proportion of Europe's gas supply has decreased, Europe's gas import has been more based on LNG. This is natural gas that can be transported in liquid form with ships. In order to be able to rely on LNG, sufficient port infrastructure and facilities are required to convert the liquid to natural gas again. Furthermore, the gas pipes must be able to handle the gas being sent in other directions than before.

It will take time to expand LNG capacity that can replace Russian pipe gas, both in terms of gas production, transport and infrastructure. Significant investments have been initiated in storage and floating regassification plants in Europe. However, some of the facilities will be ready at the end of 2022. However, Europe competes with Asia, among others, to import LNG.

Several analysis environments point out that more gas can become available and that transport and infrastructure can be expanded beyond the 2020s. Both North America and Qatar have large gas resources, and are expected to deliver large parts of its LNG production to Europe in the future. Lower gas prices will significantly reduce European power prices compared to the extraordinarily high prices we see today. It is also uncertain what will happen to the Russian gas fields that have historically delivered gas to Europe. Today it is to a small extent possible to transport it to other areas. Over time, this can change.

The development in the gas market also does not only depend on the production and transport of gas. In many parts of Europe, gas is used for heating, and a transition to electricity will reduce gas consumption and increase power demand.

In "RepowerEU", the EU launches ambitions for a faster development of renewable power generation. This will, everything else the same, increase the supply and thus contribute to lower power prices in Europe.

Also for the Norwegian power price, European conditions will be crucial. Nor is it easy in Norway to get a lot of new power generation in place quickly. Developments in European power prices are therefore important for Norway. In addition to the inflow in the water reservoirs, there is reason to expect that the development of the supply of LNG in the global market will affect how quickly Norwegian prices are falling down to more normal levels.

Gas prices for delivery in both the short and long term are today in a falling trend. Despite historically low production in southern Norway, electricity prices fell in this part of the country during the autumn of 2022. In October 2022, the average fill rate in the EU's member states was over 92 per cent. Mild weather also contributed to lower gas consumption than normal. The improvement in access to gas also led to a reduction in European electricity prices. Lower European electricity prices thus contributed to Southern Norway to import electricity at lower prices. However, the uncertainty of how the gas market will develop in the future is great.

[Box End]

#### 11.4 Relationship between power balance and prices

The power balance throughout the year affects power prices in Norway. With a high surplus, there will be net exports for many hours, including hours of low prices in our neighboring countries. The water values are low, hydropower producers are lower in price in their bidding, and we get low prices in Norway. Conversely, prices in Norway will be high this year with power deficits and contribute to sufficient power imports.

In a note from August 2022, NVE looks at the relationship between Norwegian power balance and price impact from European power prices (NVE, 2022). They are based on their long-term market analysis from 2021.

NVE finds that a very large surplus of power is required in Norway for the Norwegian power prices not to be affected by European prices. Such a power surplus can only occur this year with very high power generation, in practice corresponding to a wet year. It is theoretically possible to build such a high underlying power balance that we are not affected by European prices in normal years, but then the Norwegian production ability will be great, get less value and we must expect valuable water to play. Not least, this will be the case for wet years.

NVE has described a situation with the same international prices used in the basic projection, see Chapter 11.3.1, and calculated Norwegian prices for 30 different years. They have also analyzed a high price situation, to recreate the market situation in Europe in 2021/22. In the high price situation, there is a greater short-term price variation than in the basic case. The price difference is particularly large between the hours when renewable power is pricing and the hours when gas power is pricing.

Figure 11.13 shows calculated average annual prices in 2030 in Norway in the case of various assumptions about the power balance. Gray dots represent a power balance in a normal year of minus 5 TWh, blue dots represent the expected positive power balance of 7 TWh, and yellow dots represent a power balance of 19 TWh. See also Figure 11.3 for illustration of the various power balance scenarios. For each underlying power balance In a normal year, there are 30 dots that represent a simulated year and how it turns out in price given the different power balance. The light blue shaded field shows the range in the expected power price in Germany and the United Kingdom for different years. There is a clear connection between the power balance and the power price: the lower the national power balance, the higher the prices.

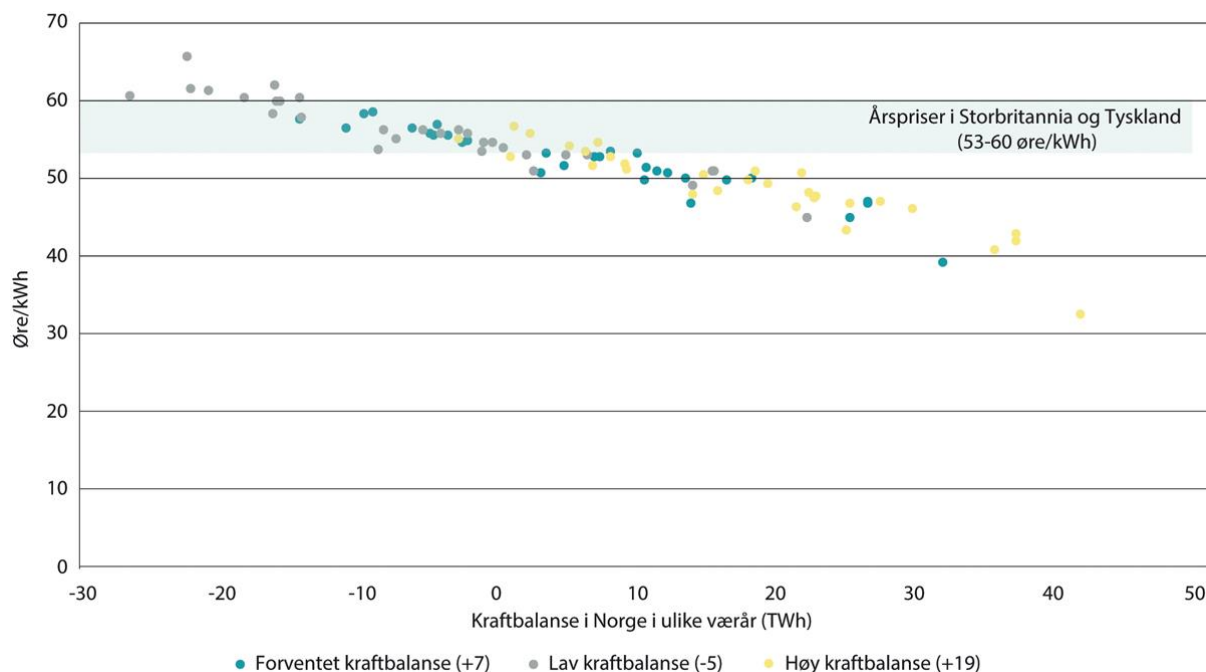


Figure 11.13 Average power price in Norway (øre/kWh) in 2030 and Norwegian power balance (TWh) for 30 different years in the basic lane (expected power balance), low power balance and high power balance

NVE (2022).

The link between the power price in Europe and the power price in Norway is strong in all scenarios, but a high power balance contributes to a somewhat lower price level in Norway than a low power balance. With a low power balance, in dry years, we will receive higher average annual prices of power in Norway than in Germany and the United Kingdom. This applies to both price scenarios, but is more often done in the high price situation, see Figure 11.14

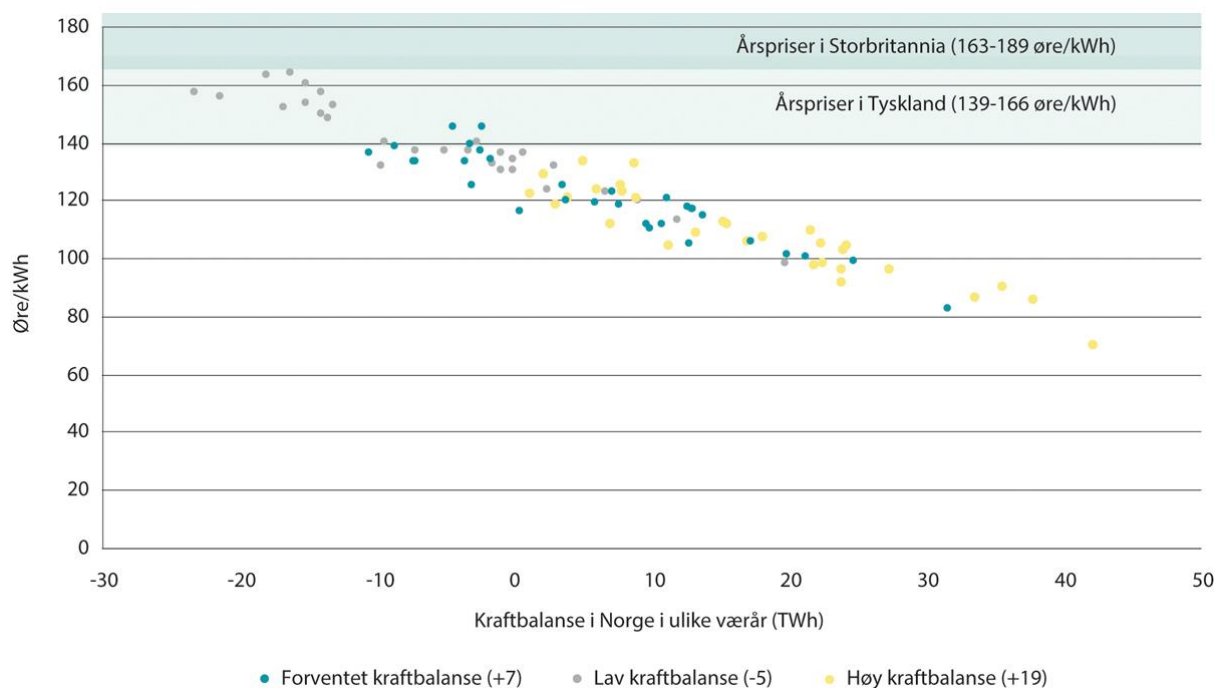




Figure 11.14 Average power price in Norway (eur/kwh) in 2030 and Norwegian power balance (TWh) for 30 different years in the high price situation

NVE (2022).

In the high price situation, the supply curves in the European countries are steeper, and the price variation greater, which gives more price effects of different power balances. When the price variation in Europe is large, small changes in the Norwegian power balance can cause a big change in the price in Norway. In the event of a strong power balance in Norway, there can be power exports for many hours of the day. Then the value of saving water for the future will be lower, that is, the Norwegian water values will be lower than prices in neighboring countries. At low power balance, on the other hand, there will be greater reason to save water for later periods. Then the water values will go up, and Norwegian prices rise. Thus, there will be several hours of high price in Norway, and less exports.

At very high surpluses, bottlenecks abroad will cause the power to be "locked in" in Norway, and Norwegian prices fall significantly below average prices in Europe. NVE's model results show such a disconnect of the Norwegian power price for power surplus of around 40 TWh. In such situations, the power producers see a high risk of overflow and therefore value the water lower. Years of very high surplus in Norway will in isolation be beneficial for Norwegian consumers, who will receive significantly lower power prices. On the other hand, years with large surpluses of power will mean that parts of the potential power generation in Norway are not used, but go to play. In addition, the establishment of such a large surplus of power will have significant costs in the form of nature interventions, large investment costs and reduced public income.

### **11.5 Commission's reviews**

The last year's power prices in Europe and southern Norway are unparalleled, and scenarios similar to the current situation are also not represented in the analyzes The Energy Commission has studied. Reduced gas supply creates major challenges in the power sector in the short term. The crisis in the gas market can cause the restructuring to occur faster than before. There is great uncertainty as to how much gas will play in the European power market in the transition to the renewable society.

The climate challenge means that adjustable production from coal and gas power plants in Europe is reduced, while the element of non-regulated production from renewable and weather-dependent sources such as wind and sun is increasing. Nuclear power is also phased out in some countries, while other countries increase capacity. See discussion in Chapter 7.

From the 1990s onwards, the import of power for dry years was mainly based on nuclear power, coal and gas power production from our neighboring countries. This thermal production in surrounding countries has been important for Norwegian security of supply, even though it exposed us to variations in prices of coal and gas.

The indirect effect European prices have on Norwegian prices through the water values will continue to be central to the Norwegian price formation. The exchange of power between the Norwegian hydropower system and the thermal systems has contributed to increased the value of regulatory ability in hydropower. Norway has been able to import when prices are low (typically at night) and export when prices are high (day) out. As other countries have received more unregulated production, such as Denmark, hydropower producers in Norway have been able to hold back production when it has blown a lot and produce when it has been windy. Although the systems around us change and the exchange pattern becomes less regular, we can still utilize these differences through power exchange. At the same time, we will be less vulnerable to short -term fluctuations than the systems on the continent, which

have less flexibility. Although they will eventually also increase flexibility on the continent, this will probably be using significantly more expensive technologies such as batteries, consumer flexibility, etc.

A European power system based on unregulated renewable power must have greater installed performance than in a thermal system, due to the variation in solar and wind power production. This means that periods of significant profits can occur in Europe and thus increased opportunities for Norway to import power at low prices and store surplus production in hydropower magazines.

### **11.5.1 Flexibility for less vulnerability**

In a renewable power system, both production and consumption will be needed to adapt to the periods of low sun and wind. Norway has a much better starting point than other countries because hydropower is flexible with large storage opportunities.

Power prices in Norway are strongly linked to prices in Europe. Although no current situation has been taken into account in the long-term power market analyzes, some of the principled assessments may still be valid. All analyzes point out that gas and CO<sub>2</sub> prices will be important until 2030 and that the prices of other alternatives will be more important in the longer term. How large the price differences between different periods and areas will be depends on whether flexible technologies are established which can use electricity during low-price periods and/or supply electricity during high price periods. Changes in the network, both internally in Norway and abroad, will also affect the price differences. Among other things, batteries, hydrogen production and consumer flexibility can be flexibility sources that can utilize the price differences in Europe. The restructuring of the energy sector depends on flexibility in both production and consumption. Norwegian hydropower utilizes the price variation today, and will continue to do so in the future. Flexibility resources with low costs will reduce the highest prices, thus reducing both price variations and price levels in Europe.

### **11.5.2 International energy cooperation to safeguard Norwegian interests**

As the development in Norwegian prices in the future will also be affected by developments in Europe, it is important to safeguard Norwegian interests in European cooperation. Through the exchange of power, Norway gains access to imports during dry periods, increased value of flexibility in all years, and provision this year where the inflow is large. This will still be valuable in the future.

Europe's response to the flexibility challenges will be crucial for Norwegian prices. This provides both opportunities and challenges. The possibilities are that Norway can have a high value of the flexible resources. It is then important that Norwegian interests are safeguarded in the event of any changes in the European regulations for the power market. The increased export capacity from Norway towards the continent allows the magazines to be emptied faster, while the value of adjustable power can sometimes result in a very high price level in Norway, primarily in southern Norway. In sum, this may present challenges for the electricity price level for Norwegian electricity customers.

It is also conceivable that dry years in Norway can coincide with cold years, little wind and limited flexible European production sources. It will be reduced in both Norwegian and European interests that the vulnerability of such situations is reduced.

### **11.5.3 Prices that provide legitimacy in the population**

The legitimacy of the energy sector in the population is influenced by many different factors, including price developments. It is important that the price level is not too high and is perceived as unmanageable.

As several analyzes show, pricing volatility in the future can be high. Although periods of very high prices are equivalent to periods of low prices, price variation in itself can also be difficult to handle. Professional players will probably be able to protect themselves against price variation, but it may make sense to make sure that households and less business also have a better opportunity to secure. Either through consumer flexibility, through energy efficiency measures that limit the use of power during typical high-price periods, or purely financially through insurance or fixed price agreements. The authorities have several different types of instruments available, both distribution policy measures such as power support, housing support, etc. and energy policy instruments in energy efficiency.

#### **11.5.4 to utilize Norwegian advantages to improve competitiveness**

A competitive Norwegian economy means that we are able to exploit our comparative advantages. Good production resources can be such an advantage, and their utilization will probably provide better conditions for industrial companies that need a stable power supply at prices lower than in other countries. If Norwegian production resources can be developed profitably, but energy policy is a barrier to industrial development, however, it will be uncertain whether consumable establishments are carried out. It can also have an impact on achieving climate and industrial policy objectives.

However, the outcome room for the development in the power balance and the power price trend is great. Multiconsult and Thema's review of uncertainty factors and drivers show that the assessment environments especially point to uncertainty about the development of offshore wind, hydrogen and industry. The development of the Norwegian power balance towards 2030 and beyond depends largely on how fast and how much consumption growth is. In these areas, the analyzes are significantly spreading.

The Energy Commission believes that the analyzes should assume a consumption growth that is in line with the climate goals. Total consumption growth will depend both on the installation of climate policy and other industrial growth. Given a large consumption growth, a positive power balance and competitive prices depend on how much production increase and energy efficiency are being carried out. NVES and Statnett's analyzes are spreading about 10 TWh in production increase by 2030, while both analyzes assume that the power balance is weakened. The Energy Commission emphasizes that there will be a great need for production increases and energy efficiency in the years to come. If the power balance is not strengthened, by rebuilding a significant production surplus this year with normal inflow, prices in southern Norway will be far from the way-and in the worst case, the European price level.

## **12 Security of Security**

A good and safe supply of energy is one of the basic supplies from the authorities of citizens. A reliable power supply is a very basic prerequisite for society's functions and for our welfare.

Over time, the requirements for security of supply have been higher. In the Norwegian energy system, electricity already plays a major role, and new sectors will be electrified at high speed towards 2050. When society becomes more dependent on electricity, security of supply becomes correspondingly more important and at the same time more demanding to maintain. In the future, energy policy must facilitate a power system that can handle both a lot of new renewable power generation and increasing power requirements.

Ensuring good security of supply requires coordination and planning, both in the short and long term. The authorities have both a responsibility and a number of tools to ensure security of supply.

The Ministry of Petroleum and Energy (OED) has overall responsibility for the power supply. Responsibility includes Concession policy, grid development and the organization of the power market. The OED also has overall responsibility for energy efficiency. The Ministry manages the Energy Act and thus the division of responsibilities between the actors in the energy system and their room for action.

NVE is responsible for the license treatment of power generation plants, electricity and district heating infrastructure. NVE has a continuous overview of the power situation and magazine filling, and oversees, among other things, the power supply preparedness. The independent regulatory authority for Energy (RME) ensures that the players comply with the regulations, and are responsible for regulating the grid companies and the physical power markets.

Statnett is responsible for security security at all network levels. They safeguard the responsibility for balancing ongoing use and production (system responsibility) in an interaction with other grid companies and manufacturers.

The daily operation of the power system is largely based on market solutions, where the price gives signals of Knappe t and excess power and net. The market makes a significant contribution to security of supply, as long as the price in the market reflects real scarcity of energy and transfer resources.

## **12.1 What is security of supply?**

Security of supply for electricity is the power system's ability to continuously deliver current of a given quality to end users, and includes both energy safety, power safety and reliability/delivery relief. The flexibility of the end users is also important for the supply of supply for electricity. However, the conceptual apparatus used to describe the security of supply is linked to the power system, with the regulations and systems that must be in place to secure momentum deliveries.

### **12.1.1 Energy Safety**

Energy safety is the ability to cover power use over a long period of time, for example through a cold winter or a dry year. The power balance, the storage capacity and the fill rate in the magazines, as well as the transfer connections within Norway and abroad, are important sizes in the assessment of energy safety, see also Chapter 11.

It does not have to be a large surplus of power in a country to get good energy security. Foreign connections and good relationships with trading partners can also secure energy security. Norway today has a power surplus of 20 TWh in a normal year. In dry years, there will still be deficits on energy, and Norway has since the 1960s imported power from neighboring countries in such years.

In their report for the Energy Commission, THEMA and Multiconsult point out that energy button will materialize in the "spring bin" in the spring when the magazines have been drained after the winter and the snow melt has not yet started. The risk of energy button in Norway is largely resolved by importing power from neighboring countries through foreign connections, but the multi -year magazines also play an important role (Thema and Multiconsult, 2022).

By 2030, power consumption is expected to increase more than power generation, and we will have a tighter power balance. It provides weaker energy security and makes Norway more vulnerable in dry years (NVE, 2021).

### **12.1.2 Effect Security**

Power safety is the power system's ability to cover the torque power use, that is, at any time. Good effect safety requires the capacity to meet the demand in individual hours with high power use. Strongness on power can occur even if there is no energy shortage, as there is grid capacity and installed performance in the power plants that determine the available effect.

The power output in the power system varies widely. Norway has a power consumption that follows season and temperatures. The power peaks typically occur in the morning or in the afternoon on the coldest winter days, when households use electricity for heating, cooking and electric car charging while at the same time full activity in business.

The access to adjustable hydropower has meant that Norway has historically had access to more effect than we need. The trend ahead is that the power output in Norway is increasing, and that it increases faster than energy consumption. The highest consumption measured for a single hour in Norway took place in February 2021, and was 25 230 MWh. At the same time there was a production of 24 676 MWh. In the relevant hour it was imported from Denmark and exported to Sweden. The production record in Norway of 28 170 MWh was set in December 2021.

The trend of increasing power requirements is expected to continue until 2030. Norway's power surplus today is already small. NVE's analyzes (NVE, 2022) show that the power surplus is around 0.5 GW, even in the tightest hours, if a moderate flexibility in today's consumption is used (1.6 GW). With a low degree of flexibility (1.1 GW), the lowest assumed available production capacity will just cover the maximum flexible consumption (both 25.8 GW), and there will be a balance between power requirements and the available effect in the very tightest situation. The power surplus is expected to be tighter in both Norway and the Nordic countries towards 2030 (NVE, 2022). This is a new challenge for Norway.

### **12.1.3 Relief and delivery reliability**

Relief safety is the power system's ability to avoid operational disruptions. Security of supply must be secured in the very short -term - the current should always be there, and stable have the right voltage and frequency.

In the operation of the power system, frequency and voltage must be kept within specific limit values, and power flow in power lines must not exceed the line's limit values. Events in the power system, such as the outcome of transmission connections, extreme weather or errors, may interfere with the power system. Then the network company must take action. If imbalances arise, Statnett as a system manager must restore the balance sheet by adjusting either production or consumption.

Delivery reliability is related to the availability of electricity and can be measured by the number of interruptions in the power supply and the duration of the interrupts. It is difficult to protect against unwanted events, such as extreme weather. Ensuring a completely interruption-free power supply will require very large and unrealistic investments in infrastructure and production facilities. However, delivery reliability in Norway has generally been good, over 99.96 per cent since 1998. In 2021, delivery reliability was 99.98 per cent.

In the Delivery Quality Regulations in the power system, requirements are set for, among other things, voltage quality and the restoration of supply without undue delay in case of interruption. Through the revenue framework regulation and the KILE scheme (quality-adjusted income limits by non-provided energy), the grid companies are given financial

incentives to take into account the interruption costs when making profitability assessments in investments in the network and any other measures.

The ongoing operation of the system will be more challenging in the future. The need for flexibility to balance the power system increases for several reasons. First, there are several large units in the system, most recently with the German cable (Nordlink) of 1400 MW. Statnett must have flexibility resources to handle a sudden outcome of such large units. Second, system operation becomes more unpredictable with an increased proportion of unregulated production in the system and more foreign connections. A large proportion of flexibility resources may have to be used to handle sudden changes in production and flow in the system, and there will be less resources left to handle a possible outcome of the largest unit. More unpredictable flow and several bottlenecks in the system provide a need for flexibility resources across the country.

A completely interruption -free power supply cannot be guaranteed. Actors who depend on an uninterrupted power supply, such as hospitals, must provide alternative supply through emergency power units or other solutions. The vulnerability of society to interruptions in the power supply is therefore also dependent on the degree of self -preparedness in end users.

We live in a time of war and unrest in Europe, and it can affect the reliability of the power system. Being prepared for efforts to meet extraordinary situations such as war, major accidents and natural disasters are included in the emergency work.

Preparedness in the power supply is regulated through the regulations on safety and preparedness in the power supply. The contingency regulations include, among other things, requirements for the organization of a separate contingency organization called the power supply's emergency organization (KBO), which sets the cooperation structure for coordination and management of the power supply. KBO should be able to effectively handle and prevent events in the power supply. KBO consists of NVE, Statnett and larger power producers, grid companies and district heating companies that have a significant impact on operating or recovery of production, transformation, transfer, turnover or distribution of electrical energy or district heating.

### **Box 12.1 changed threat to energy infrastructure**

In September 2022, several explosions were recorded at the gas pipelines North Stream 1 and 2 which carry natural gas from Russia to Germany via the Baltic Sea. Shortly after, gas leaks were reported from the pipelines. The EU and several countries pointed to sabotage as the probable cause.

We are facing a changed threat to energy infrastructure that also challenges reliability. The Total Preparedness Commission was reduced in 2022 and, as part of the mandate, which includes the entire field of social security in Norway, will assess the preparedness and handling of undesirable incidents related to the power supply as a critical social function. This commission will submit its report in June 2023. The Energy Commission does not enter into assessments and recommendations related to emergency issues. Reference is therefore made to the Total Emergency Commission's work to describe the organization of emergency preparedness in the power system, and assessments of how the current threat image should be handled.

[Box End]

## **12.2 What strengthens the security of supply?**

### **12.2.1 Energy use**

It is the needs of consumers and businesses that are the starting point for investing in energy production with associated infrastructure. This need can be changed through different types of investments and adjustments on the consumption side. What happens there can thus also have an impact on security of supply.

Energy efficiency measures can contribute to better energy balance and power balance. Some measures have a greater impact on the balance of effect than others, especially efficiency that lowers winter consumption. Heating can also be stored in buildings, both in water -borne heat, hot water tanks, underfloor heating and in the building body.

Consumption flexibility means that consumption is cut for short periods or moved from the top load hours to other hours of day.

Consumer flexibility has the potential to contribute significantly to the security of supply going forward. However, it will require the development of markets and systems, see Chapter 9.5.

Price variations give important signals to consumers about profitability by adapting power consumption. Good information about your own power use, for example through smart power meters (AMS), enables consumers to calculate profitability by taking measures to get a more efficient and flexible energy consumption. It has been shown that lack of information on price causes fewer households to respond to price signals (Statnett, 2022).

Statnett has developed market mechanisms and other tools to utilize flexibility, and several mechanisms are under development. Statnett also already has agreements with the industry industry, which is an important source of consumer flexibility in scarcity situations. A number of demonstration projects are ongoing to develop alternatives to web investments. The projects are aimed at all sectors, and include many technologies and market solutions. Networking companies (DSOs) are also working on solutions to avoid or postpone online investments. Box 12.2 gives some examples of this.

### **Box 12.2 Examples of gains by avoiding or postponing online investments**

The THEMA report "Profit realization of the DSO role" (Thema, 2021) Reference is made to several examples where network companies have achieved a significant gain by avoiding or postponing new online investments. Below are some of the examples mentioned in the report:

- «Arva has avoided a net investment in the order of NOK 300 million in connection with the connection of a new wind turbine in the company's area. This was achieved, among other things. Through an agreement with Statnett on the installation of system protection, an agreement with the manufacturer on connection with terms and temperature upgrading of an existing line.
- Agder Energi Nett points out that the scheme related to terms in a concrete example can provide savings in the hundreds of millions. The company has a pilot project where consumable flexibility can be an alternative to investing in a new transformer station. However, control of the handling of bottlenecks in its own network is a prerequisite for such a solution.
- Eidsiva Nett (now Elvia) has conducted an analysis showing that a similar gain could have been realized by using flexible consumption, special regulation of production or batteries.
- Tensio has increased the capacity of installing equipment to control the consumption of two consumption customers according to the capacity of the grid. Here, the most important thing is that the network company takes the initiative to find solutions

within the current regulations. However, it is uncertain whether the incentives to maximize the utilization of the network are strong enough in the current regulation. ”

Thema (2021)

[Box End]

### **12.2.2 Replacement of energy carriers**

A variety of energy carriers provide better security of supply. Power can in many contexts be replaced by other energy carriers such as thermal energy, biogas and biomass. Previously, petroleum products and natural gas have been relevant substitutes for electricity. Heating of buildings and tap water are examples of consumption that can be covered by more energy carriers than electricity, and with effective heat pumps. Wood firing, other bioenergy resources and utilization of waste heat in various forms can also reduce the power consumption during high load periods. Replacement of energy carriers assumes that alternative heating systems are installed. The price of the various energy sources will be decisive both for assessing profitability by installing flexible systems and for choosing an energy source in the operating phase.

Climate policy changes which alternatives will be available. The ban on fossil oil firing in buildings is an example of that. Some alternatives can fall away, and in this way reduce flexibility. At the same time, new solutions will emerge and draw in the direction of increased flexibility, such as electric cars or increased digitalisation. In Chapter 9, efficient and flexible energy consumption is discussed in more detail.

### **12.2.3 power trading**

Possibility of imports from the Nordic countries, the UK and the continent reduces the vulnerability of variation in inflow, temperatures and power consumption. At the same time, the dense market connection exposes us to the vulnerability of other countries' power systems.

The EEA Agreement and other legal and political agreements with the EU and the UK provide a framework for understanding and ensuring security of supply in Norway. The regulatory development in the EU is fast, and what the future power market will look like is uncertain.

### **12.2.4 Power production**

Adequate power generation and reasonable magazine disposal are important for both energy and power safety. A larger surplus of power in the normal year makes it less likely that energy shoulderness can occur in dry years, see Chapter 11. The adjustable hydropower allows to save water in the magazines, and to shift production between different periods.

The power market facilitates the manufacturers to dispose of the water effectively for the benefit of society. Expectations of high winter prices motivate hydropower producers to hold water back in the spring bin magazines. The central driver of this is the price formation in the market and the signals it gives the manufacturers about the value of the water in the magazines. Apart from the requirements for minimum water flow and the minimum magazine level, the authorities do not set specific requirements on how the magazines should be disposed of.

The size and location of the power plants are important for security of supply. In Norway, the power plants are where the natural resource exists, and it has given us a geographical power plant fleet



The authorities basically have limited opportunities to determine the scope and location of new power generation. However, the scope has to some extent been driven through various support schemes. Power development depends on the authorities having granted a license, and in the treatments of licenses, different conditions can be given weight. The authorities emphasize, among other things, adjustability and regional deficits to safeguard security of security of supply. The concession treatment is also subject to political governance, and it affects both the type of power generation that comes and where it comes.

### **12.2.5 Price and price areas**

Market prices play a key role in security of supply. Both production and consumption respond to prices. The various analysis environments expect that prices will, on average, stabilize at a somewhat higher level in the future than we have seen over the last 30 years, see discussion in Chapter 11. They also expect that we will get greater variations in the electricity price over the day, from day to day, from season to season and from year to year.

Prices and price expectations give signals about the measures that contribute most to securing security of supply, and the profitability of different adjustments for electricity users and manufacturers. As discussed in Chapter 9, power customers may consider profitable adjustments in the short and long term on the basis of prices. Manufacturers can assess technologies, dimensioning of plants and the value of various energy storage opportunities on the basis of prices. Proper prices also have a crucial significance for the magazine disposal and the power flow between regions. The players in the power system use the prices for the disposal of the power throughout the year, and it is therefore important that power prices reflect the fundamental conditions in the power system.

Because the power grid does not have the capacity to completely equalize the differences in power surpluses and deficits between the regions, the country can be divided into price areas where different power prices can be formed. Area prices contribute both to the handling of scarcity in the shorter term, and highlight the need for long-term measures.

Price areas may have different regional power situations, and at times some areas may be more vulnerable than others. Conditions such as weather and inflow, consumption patterns and transmission capacity internally and to other areas are involved.

In areas with excess power, prices will be relatively low, and there are opportunities to export power. In areas with deficits, there will be higher prices and need to import power. Typical for Norwegian conditions is that the supply of power is affected by geographical variations in inflow. Price areas, for example, contribute in the short term to manufacturers in an area with a lot of inflow do not produce as if the transmission capacity was unlimited.

In a scarcity situation, the area price will contribute to better security of supply because it provides incentives for increased power generation and reduced consumption. In Norway, where energy access to the hydropower plants varies with regional weather conditions, the price areas contribute to the efficient use of energy resources. In the longer term, area prices give signals to the market where there is geographical shortage or profits in Norway. It helps to show where it will be beneficial to locate new production or new consumption, and the value of investments in the grid.

When using price areas that reflect restrictions on transmission capacity, the online restrictions will be reflected in the power price and mainly handled by the market. An alternative to prices reflecting the online restrictions are so-called countermeasure. In countermeasures, manufacturers and consumers are paid by the system operator to regulate up or down production or consumption after the market has cleared. In an area where there is too much production compared to consumption, manufacturers will typically get paid to

reduce their production. In a system of price areas, on the other hand, the limitation in transmission capacity will be reflected in the price, and the manufacturers with the most expensive offers will not receive aggregate. This thus entails high costs for the system operator - costs covered by the online customers.

In Europe, few countries are divided into price areas. Germany has large online restrictions between different regions, but is not divided into price areas. It helps the counter-trading costs to be high. For 2020, they were estimated at about 1.4 billion euros by the German regulator Bundesnetzagentur (Bundesnetzagentur, 2021). About half of the costs are not directly to the bottleneck management, but also online challenges due to Germany's facility of support for renewable power generation. Much of the wind power production in Germany is located in the north of the country, and a price area breakdown would probably result in lower prices in northern Germany than other areas. It would also have meant that the German influence on Norwegian prices would be different than today, and it could have given somewhat lower Norwegian prices.

### **12.2.6 The power grid**

A well-developed power grid is a prerequisite for safe supply of power for the users. Stronger network connections between the price areas can increase energy flexibility, and Thema and Multiconsult have pointed out that new weather and commercial patterns may indicate that it would also make sense to strengthen the central grid also beyond Statnett's current plans (Thema and Multiconsult, 2022).

The power grid is a natural monopoly and is therefore strictly regulated. The network companies are required to associate end users and manufacturers to the grid, and must plan and operate the network in a way that ensures sufficient capacity. For the grid companies, the development in power use is largely an external factor, but they can affect the development somewhat through tariffs and other terms.

The network is self-financed and the network companies are regulated so that they can cover their costs and get a reasonable return on invested capital given efficient operation.

In the short term, supply security is safeguarded through the operation and maintenance of the power grid, and flexibility in the production and use of electricity. For example, so-called SFHB companies ("large consumers with high useful life", at least 15 MW for more than 5,000 hours) today a high and stable power consumption that can help ensure adequate short-circuit performance, and in this way be beneficial for management of the power grid. Statnett is currently building the transmission network so that one can withstand the outcome of a single component without losing the power supply. Flexibility is also utilized in large adjustable power plants in order to operate the power system efficiently.

It takes a long time to plan and expand grid systems, and longer than to establish new power consumption. At the same time, there is uncertainty about where and when the new consumption comes, and in what size. In recent years, there has been a significant increase in demand for grid capacity, and it is expected to continue to increase. The transition to the low-emission society, increased electrification and establishments of the new power-intensive industry provides expectations of significantly increased power use, and thus also increased need for grid.

It is mainly the direct regulations of the grid companies, such as the obligation to attach, that must ensure that necessary investments are made. The income regulation will help to make the investments made in an efficient way, and that the grid companies make the right trade-offs between measures in operations, such as better utilization of existing grids and the need to invest in new grids.

The Power Network Committee was appointed in June 2021 to look at measures to reduce the time it takes to develop and licensing new facilities, safeguard a socio-economic development of the network with great uncertainty about the consumption development and look at possible improvements in the system of connection duty. The committee delivered its report in June 2022, NOU 2022: 6 "Nett in time - on the development of the power grid". Today's situation, and further electrification in the future, indicate that measures are needed. The power grid committee has made a number of proposals to strengthen and speed up the network development, enable faster and simpler connection and ensure a more socio-economically rational network development. Through the measures, the Power Network Committee believes that there can be significantly reduced lead time for grid systems, better utilization of today's network and reduced need for prioritization of the queue.

### **12.3 strained power situations**

Price signals mean that some consumption is reduced in scarcity situations, both in business and households. In this way, the price acts as a rationing mechanism. A good number of consumption are price independent, such as a large part of the power consumption in most households in Norway, and this must be covered by production and import. If it cannot be covered, there will be some form of rationing where the consumption in the price area in question must be shortened.

In order to reduce the likelihood of rationing, a separate regulatory framework has been established in Norway to handle strained power situations. Statnett assesses the power situation and is responsible for developing instruments to handle very strained power situations (scissors). Statnett defines scissors as a situation with more than 50 percent probability of rationing, which is the fourth level on a five-speed scale:

- Green: Normal power situation
- yellow: tight
- Orange: strained
- Red: very strained
- Black: Rationing of Power

The Energy Act contains a provision for rationing that can be implemented when extraordinary matters so require. NVE is the rationing authority and responsible for planning and administrative implementation of measures in connection with power rationing. NVE has its own regulation on rationing.

Statnett makes ongoing assessments of the power situation. In May 2022, Statnett changed the assessment for southern Norway for the upcoming tapping season from Normal (green) to tight (yellow). A tight power situation means that there is between 5 and 20 percent probability of rationing, before extraordinary measures have been taken into account. Statnett justified its assessment that the hydrological situation in southern Norway was weaker than normal for the season, and an unusually major uncertainty as regards the possibility of imports due to reduced Russian gas deliveries to Europe. In November 2022, Statnett changed its assessment for southern Norway back to normal (green). The reason was a lot of rainfall, low power generation, reduced consumption and adequate imports.

#### **Box 12.3 Assessment of future case measures**

In the autumn of 2022, Statnett investigated the need for future case measures especially related to the winter of 2022-2023, after ordering from NVE. Until spring 2023, Statnett recommended the following measures:

1. Maintain and further develop the follow-up of manufacturers to ensure that sufficient water is kept through the tapping season.
2. Conduct information campaigns to reduce consumption and introduce specific measures to reduce public business consumption.
3. Enter into an agreement to be able to run Energiverk Mongstad.
4. Enter into agreements with industrial companies on reduction in consumption if the risk of rationing increases beyond winter (energy options).
5. Activate energy options and/or start production at Energiverk Mongstad.

Statnett considered it in principle important to continue that it is the market players, through the market, that has the main responsibility for minimizing the likelihood of rationing. Measures to improve the situation must build up and clarify this principle. At the same time, it is important that measures that are considered introduced do not weaken important incentives such as price signals and corporate social responsibility in those who have the best prerequisites for implementing sound magazine disposal.

[Box End]

#### **12.4 Dry year protection is important**

Our power system is affected by the weather, and thus the security of supply is also affected. The power balance varies with precipitation conditions and inflow, and there can be large deviations between dry years and wet years in Norway. The high hydropower share in the production system means that Norway has special challenges in terms of dry year protection.

The most important sources of energy safety and energy-fixibility in the Norwegian power system today are multi-year and seasonal reservoirs and import capacity. The multi-year magazines are built so that we can produce in dry years and fill in wet years, and in this way level off the large natural variations. However, the Norwegian power system is vulnerable to longer periods of low inflow.

The Norwegian power system is entirely dependent on sufficient inflow to the water reservoirs. This is in contrast to the European power systems, which have been based on production where the fuel can be purchased. Several dry years in a row can provide significant energy button in Norway, which in turn can be critical for security of supply. Energy challenges materialize in the spring bundle in dry years, cf. Chapter 11.

The connection to our neighboring countries affects the Norwegian water values and the magazine disposal. The countries around us are planning for phasing out their thermal production capacity and are in the process of developing non-regulated and weather-dependent renewable production. We are heading towards a more volatile power market and an uncertain development in Europe, especially in the years to come. As discussed in Chapter 11, the future situation in our neighboring countries can contribute to increased security of supply for us. Long periods of access to wind power on the continent can be conceived, which provide great potential for imports and thus the opportunity to save water in our magazines. At the same time, the current situation shows that there can be good reasons for thinking through how our need for dry-year protection is covered when the outside world experiences shock or undergoing revolving changes.

The Government's review of the power situation in 2021-2022 revealed that the Norwegian power system is vulnerable to unexpected incidents and weather variations, see Chapter 3.

#### **Box 12.4 New Mechanism Management for magazine disposal**

In light of the uncertain situation for European energy supply around us, the vulnerability of Norwegian power supply is higher than before, for example for unexpected incidents and for inflow. Following a review of the power situation in 2021-2022, the government announced in the fall of 2022 that they will introduce a management mechanism to ensure domestic power security for power.

The mechanism should be designed to ensure that more water is saved when the magazine levels are low. The Ministry of Petroleum and Energy's work to assess how a new management mechanism can be arranged is done in collaboration with NVE. The work was not presented when the Energy Commission completed its report.

[Box End]

We cannot take into account everything, but we must take into account our vulnerability and for the unforeseen to happen. The interaction with our neighboring countries must safeguard security of supply for all parties in the best possible way. At the same time, Norway must have a room for maneuver to secure national security of supply, especially related to inflowing failure, due to the special position we are in as a hydropower country. There are different opportunities here.

### **12.5 Measures in the magazine disposal**

Normally, the power market should work in a way that causes supply security to be safeguarded. However, unexpected incidents that the market is not equipped may arise and that the manufacturers cannot be expected to predict. SINTEF's study of the power situation 2021-2022 shows that high European power prices and the expectation of normalization of the price picture a little further in the future led to a strong drainage of the magazines in the fall of 2021, see Chapter 3.

The possibilities of introducing special measures to ensure that we have enough water in our magazines in the face of dry years have previously been proposed and investigated in connection with various power market situations. Most recently, the consulting companies Afry and Menon have considered magazine restrictions as measures in connection with the investigation of the power situation. This is discussed in more detail in Chapter 3 and in the Ministry of Petroleum and Energy Prop. 1 S (2022–2023).

From a security of supply, temporary requirements in the winter season and through the energy crisis in Europe may be rational. One challenge is that it is difficult to know when to introduce requirements, and that such requirements will both lead to games of water which in turn can increase the likelihood of scarcity. Rather, more permanent schemes should be considered when we have more knowledge about the development going forward.

A short -term solution may also be to temporarily relieve minimum water flow requirements, or temporary requirements for minimum water levels in the magazines in dry years beyond given licensing requirements. Such reduced requirements will make it possible to save more water and have an energy reserve that can be used if the danger of rationing becomes acute. This will require legislative amendments, and both alternatives must be weighed against nature and the environment, which is the reason for such requirements being initially set.

#### **12.5.1 Regulation of power trading**

Power exchange strengthens supply security by providing the possibility of imports in dry years or when the underlying power balance is weak. If we get two or three dry years in a row, import opportunities are especially important.

We have had clear benefits from linking ourselves to other countries' power systems, while also increasing our exposure to what is happening around us. The power situation over the past year has brought out a debate with various issues related to export and security of supply. Developments in Europe give signals of a less reliable supply going forward. At the same time, increased transmission capacity abroad means that the magazine disposition is affected, which may be unfortunate in cases where we need to save water in the magazines.

Various forms of export regulation have been investigated by Afry and Menon. The results are presented in Chapter 3 and in Prop. 1 S (2022–2023) for the Ministry of Petroleum and Energy. The most relevant measures that have been analyzed are to limit the net export capacity of the foreign connections in a particular power situation. For example, limitations if the fill rate goes below a certain level for a certain period or in the probability of rationing, or to increase the cost of export in the form of an "export tax".

The impact of export restrictions in general depends on many assumptions and is very uncertain, especially in the longer term. The premise of full exports on all foreign cables at all times is not present in reality. Within periods of net exports, there are also periods of import, see also discussion in Chapter 11. Afry and Menon's simulations of export restrictions from southern Norway point to possible redistribution effects, where there are redistributions of net exports over time, to other countries and times.

A key question is whether such export restrictions will be in violation of the current decrease laugh about free trade. On behalf of the OED, the regulatory authority for energy (RME) in August 2022 provided an assessment of the legal room for action for any extraordinary measures to limit the transfer of power abroad. RME considers, among other things, that the EEA Agreement allows for export restrictions when relevant considerations so indicate, and that security of supply in RIME is such a consideration, as long as the restriction is designed in accordance with the provisions of the EEA regulations (RME, 2022).

By October 2022, Sweden was rejected by the EU's energy agency ACER (Agency for the Cooperation of Energy Regulators) as they requested exceptions for the obligation that 70 percent of the capacity can be used for export, in line with requirements in the EU's pure energy package, when it applied to transfers to Denmark and Finland. In his decision, Acer believed that Sweden was not in such a vulnerable supply situation that the exception could be granted (Acer, 2022). The same week, ACER also came out with a general press release with a warning that EU countries should limit the export of energy during times of crisis. Acer warned of pursuing national, short-term energy interests, for example by limiting exports, because other countries will suffer (Acer, 2022).

A basic element is also that in any agreement there is a counterparty. Norway is served by safeguarding our common interests with Europe. Export regulation is a major intervention in a common market that affects other countries, and we cannot exclude possible reactions. This in turn can adversely affect the security of supply in Norway during critical periods where we have import needs.

## **12.6 Security of supply in the power system in the years to come**

In the years compared to 2050, good security of supply is still a significant consideration. However, we cannot know for sure how supply security develops, especially at a time when the uncertainty has generally become greater and more complex.

Measures that help to strengthen security of supply are often long-term. Energy policy measures that will have a significant impact on the energy and power balance, such as the development of new large power generation or grid capacity, take time. The road choices

today already say something about the prospect of security of supply in the years to come. We therefore have the best conditions to say something about the development towards 2030.

The starting point for an assessment of security of supply in the future in time is the extent to which energy, power and reliability will be affected. By 2030, both NVE and Statnett expect a tighter power balance, see discussion in Chapter 11. The biggest challenge associated with the energy balance in the Norwegian hydropower system is the large variations in the inflow between years, and especially access to sufficient energy in dry years. An increase in wind power and solar power can help to make the power system somewhat less exposed to fluctuations in annual energy production. A tighter energy balance in the years ahead also comes from the fact that the lead times for new production and grid capacity are long.

This backdrop makes the possibility of imports particularly important to maintain the energy balance and get through the spring bundle without scarcity. This allows us to save more water in the magazines when there is a prospect of scarcity for dry years.

It is expected that the power balance will also be tighter. The causes are strong consumption growth and little new, safe effect from winter production. Energy challenges and effect cutting are closely linked, and a positive energy balance can also help to reduce power challenges.

In order to handle energy and power challenges in the future, both price formation, consumers and manufacturers' adjustments to prices, disposal of multi-year reservoirs and the import opportunities are central. In the short term, price formation gives signals to manufacturers to dispose of production resources so that they are available when there is the greatest need, and to consumers to change their consumption patterns. In the long term, it provides incentives to invest in more flexible production and consumption.

Energy merexibility contributes to a better energy balance and to dealing with power challenges. Overall, there is a need for increased flexibility from the consumption side to avoid high electricity prices and to ensure balance in the system at all times. Here are new and great opportunities.

### **12.6.1 on the possibilities of import**

Imports throughout the year will still be important for security of supply towards 2030, but the situation will look different than today because the transition to a more weather -based European power system means that the exchange patterns change.

So far, Norway has typically been able to import when prices are low at night and export when prices are high during the day. With more unregulated production in other countries towards 2030, the opportunities are rather that we can import power at low prices during periods of significant profits from wind and solar power production in Europe. This means that our vulnerability to dry years is changed, but it does not necessarily get bigger than it has been.

In the years to come, we can probably still utilize the system differences between Norway and Europe through power exchange. Imports from our neighboring countries during the winter will still be valuable to increase energy access in the spring bundle. It is also positive for security of supply that we will be less vulnerable to short -term fluctuations than the systems on the continent, which will have less flexibility in the coming years.

However, we must take into account that the exchange pattern can become less regular and swing more, and generally become more unpredictable. This is the change in our vulnerability. Net imports we have week by week will probably vary more, and we must expect that we will receive net exports for a few weeks when, for example, wind power

production is low on the continent and in the UK, even during periods when we have low magazine filling and need for imports to import to Ensure us against scarcity in the spring bundle (Thema and Multiconsult, 2022).

However, Europe is entirely dependent on solving its energy challenges. We do not know if climate and energy policy in the EU will succeed as it is proposed today- but it is difficult to imagine that the authorities in Europe will plan for a situation where, for example, parts of consumption must be shortened for extended periods. In the long term, Europe must compensate for the loss of stable, thermal power and respond to the flexibility challenges. The analyzes of the power systems in Europe in the long term assume that capacity will be established that can produce when there is little wind and solar power. ENTSO-E, the European Cooperation Organization for System Manager Network Company, also conducts regular analyzes and assessments of whether the power system has sufficient production capacity to meet demand. It seems rational to assume that the EU or the individual member states will in the extreme case implement measures to ensure energy supply to residents and business.

The solution to ensure stability and reserves in Europe towards 2030 is probably in the storage of surplus production from wind and solar power in batteries and hydrogen. Any nuclear power and/or gas power (with carbon capture and storage) later, if the first option does not come in place in place or becomes too costly. There is also reason to believe that the available potential for consumption flexibility will increase in other countries because it is a key prerequisite for balancing a renewable energy system. However, this means that especially by 2030 there will be variations in both prices and resource situation (Thema and Multiconsult, 2022).

It cannot be ruled out that challenges may arise with access to imports during periods, or that imports become very expensive. Initially, hydropower producers will take into account variations and risk of periods of low unregulated production in their water disposal. Today's regulation of the power market gives manufacturers incentives to avoid a situation where the magazines are drained so that there is no water left to the spring bundle. At the same time, today's water disposal is developed for today's power system, and not necessarily new types of risk. In the revised national budget 2022, the government announced that they will strengthen the knowledge and capacity to analyze the power market and the energy systems, including how the changes in the power markets around us and our connection to these markets affect Norwegian power supply.

The changes in the power systems around us can happen quickly and cause events that are difficult to predict and plan for. Also in light of the vulnerability assessments made by the Norwegian power system, as discussed in Chapter 3, there are arguments for having instruments that better ensure national security of supply.

## **12.7 Changed vulnerabilities in the energy and commodity markets**

The transition from fossil to renewable energy sources changes which raw materials, minerals and metals are in demand. In order to produce renewable technologies such as wind turbines and solar cells, but also electric cars and batteries, one depends on a variety of goods such as aluminum, cobalt, copper, steel, zinc and lithium.

Therefore, in line with the energy conversion globally, the need and demand for such metals and minerals have increased significantly in recent years (IEA, 2021) (NGU, 2021). The renewable segment is now the fastest growing market for metals and minerals, and in the IEA's net-zero scenario is expected to also increase until 2050, see Figure 12.1 (IEA, 2021).



Europe's dependence on oil and gas today can in the long run be replaced with an dependence on metals and minerals. This changes the vulnerabilities we face.

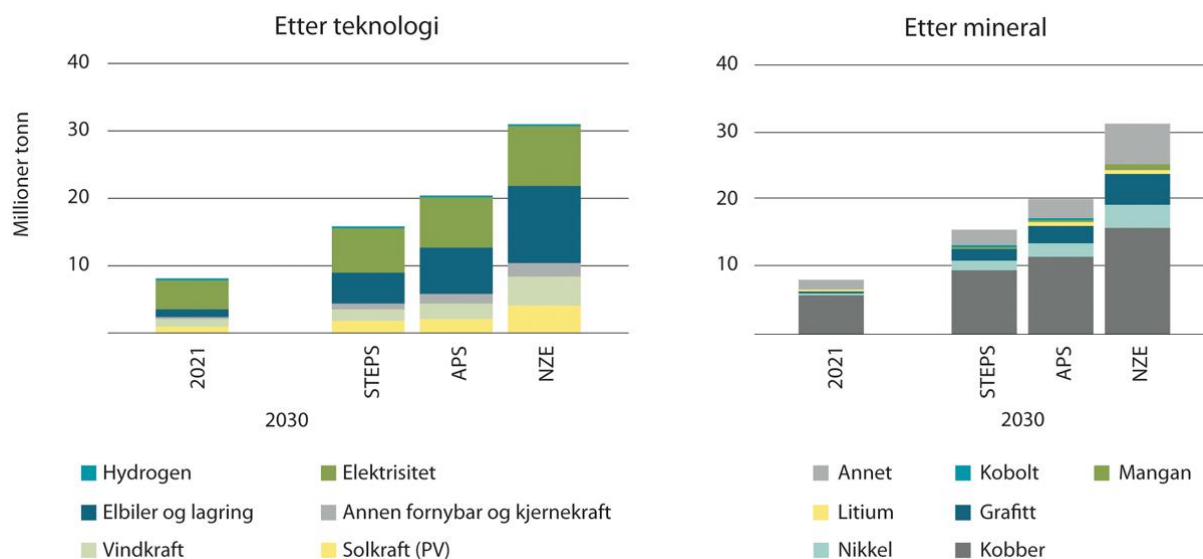


Figure 12.1 Scenarios for mineral requirements in 2030, divided into type mineral (right) and various technologies (left) 1

1 The figure is the future forecasts Steps (Stated Policies scenario), which is based on current policy, Aps (Announced Pledes scenario), where climate obligations and notified policies are used, and NZE (Net Zero emissions), which is a normative scenario in which the energis When zero emissions in 2050.

IEA (2022).

The metals and minerals that the IEA assume will characterize the energy production of the future is traded globally. This in itself is nothing new, and also applies to fossil fuels. However, the market concentration for minerals and metals is very high, even in relation to fossil energy sources. This applies to both production and processing, see Figures 12.2 and 12.3.

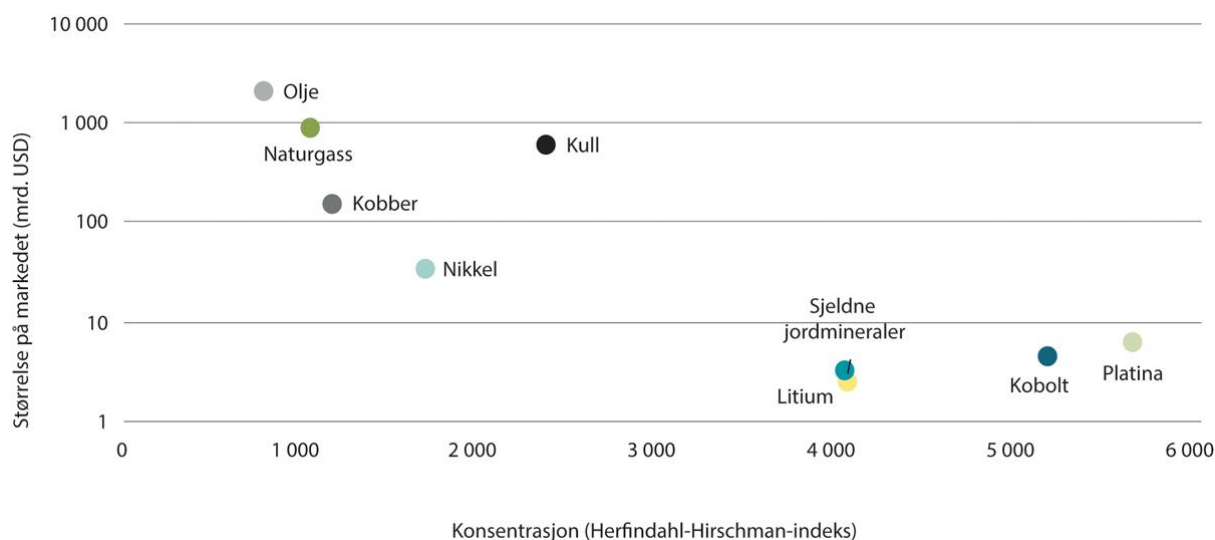


Figure 12.2 Market concentration for selected raw materials

IEA (2021).

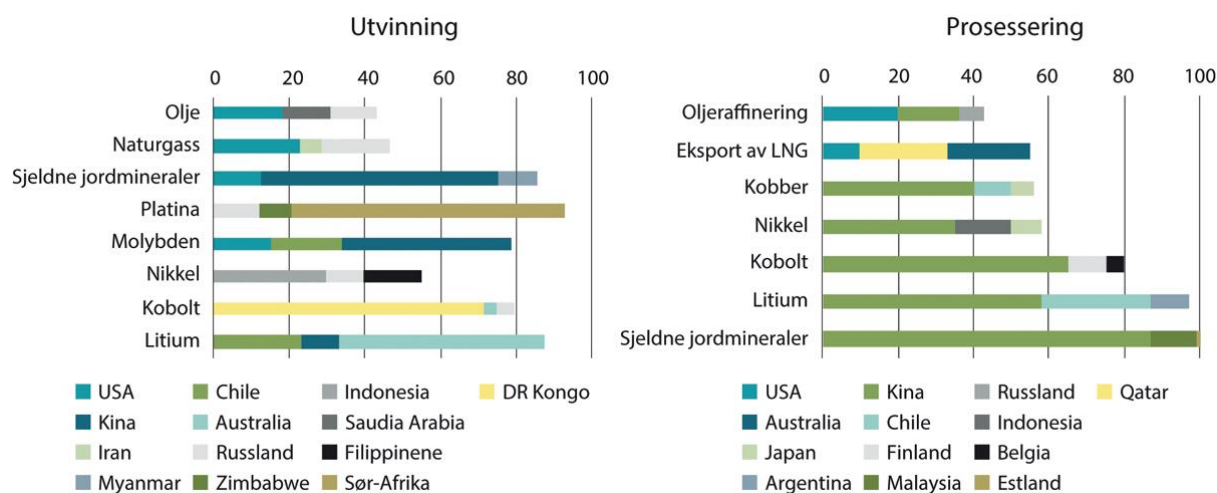


Figure 12.3 Different countries' share of recovery (left) and processing (right) of selected minerals and fossil fuels, percent in 2019

IEA (2022).

Resource accessibility often depends on national or private monopolies in areas with varying degrees of political, social and environmental risk. Trading patterns and current policies in the producer country make access vulnerable, for example, instability and export restrictions. The market competition is already sharp, and in the future minerals and metals can be even more difficult to obtain (IEA, 2021) (NGU, 2021).

The high market concentration and the composition of the supplier chains raise some new questions about access and predictability. Minerals and metals are essential for Europe to be able to adjust the energy sector and reach its emission targets. This is also the reason why the EU has announced its own action plan to reduce its own vulnerability and addiction, as well as created the Alliance Erma (European RAW Materials Alliance) to achieve the objectives in the area (Erma, 2022) (EU Commission, 2020). Access is also a stated strategic security concern for the EU, and raw materials that have great economic significance and where access is associated with risk is defined as raw materials of "critical significance".

Changes in the global energy and commodity markets provide changed vulnerabilities in future energy production. Increased market diversification, more flexible and predictable supplier chains and strengthening of the supply side of the continent are central to getting the green shift in Europe. This also affects Norway. At the same time, Norway has historically been a producer of a number of important metals and industrial minerals. Today, Norway accounts for, among other things, 6 per cent of the total silicon production in the world, which accounts for around 30 per cent in Europe, as well as 8 per cent of all European graphite recovery (EU Commission, 2020). The potential in both Norway and in the Nordic countries is still large (Eilu, 2021).

### 12.8 Energy Commission's assessments

Good security of supply is a pillar of energy policy. The most important step we can take to ensure security of supply in the future is to ensure that growth in consumption is corresponded to by growth in power generation, and thus maintains a positive power balance in normal year. It reduces the likelihood that there will be energy scarcity. If new production is mainly in the form of unregulated energy, it must also be invested in sufficient power and production that ensures sufficient frequency stability.

Overall, there are three key tools to ensure such development. The price mechanism gives signals about access to resources and to adapt energy use, and helps to avoid getting into scarcity situations. The concession policy provides guidelines on which new power plants can receive a license, while the energy efficiency policy provides guidelines for how consumption develops. Each of the tools makes important contributions to security of supply and must be given weight in energy policy. At the same time, it is necessary to ensure that the division of responsibilities and tasks is well enough designed and aimed at ensuring the security of supply as best as possible. This is especially true at a time when we move towards a tighter energy and power balance.

In a security of supply, it is especially the dry year fuse that is important in Norway. We must therefore take into account our vulnerability, but also for a new energy situation in Europe with changed vulnerabilities and for unforeseen events as far as possible.

This requires that Norway has a greater room for maneuver to secure national security of supply than today. At the same time, we must navigate in a direction that preserves cooperation with our neighboring countries and benefits security of security for all parties. Measures that are able to safeguard both considerations must be identified and developed.

### 13 The design of the power market and trade with other countries

In this chapter, we will describe key features of the design of the power market in Norway as well as the power trade with other countries. An overall description is given of how today's power system is organized, a brief discussion of structural power reforms that are now discussed in other countries, and how changes in the power system in the future can affect the power trade with other countries. For a more detailed description of consumption, production and power balance, see chapters 9, 10 and 11 respectively. From June 2022.

#### 13.1 The power market in Norway

In 1991, Norway established a market-based system for the sale of power. Today, Norway is part of a common Nordic power market with Sweden, Denmark and Finland, which in turn is part of the European power market.

The power exchange is central to the price formation in the market, especially for what is called the "Day-Ahead" market (formerly the spot market). In this market, prices and electricity flow between areas are calculated at the same time. Actors on different aspects of national borders enter their sales and purchase bids hour by hour before the next day, and do not need to reserve capacity in the grid in advance. Price formation is illustrated in Figure 13.1, where we have not taken into account the influence of trade abroad.

At any time, there are different manufacturers that can offer power. In Figure 13.1 they are sorted from left to right on the horizontal axis, where those with the lowest costs come first. The vertical axis appears the cost of each of the power sources.

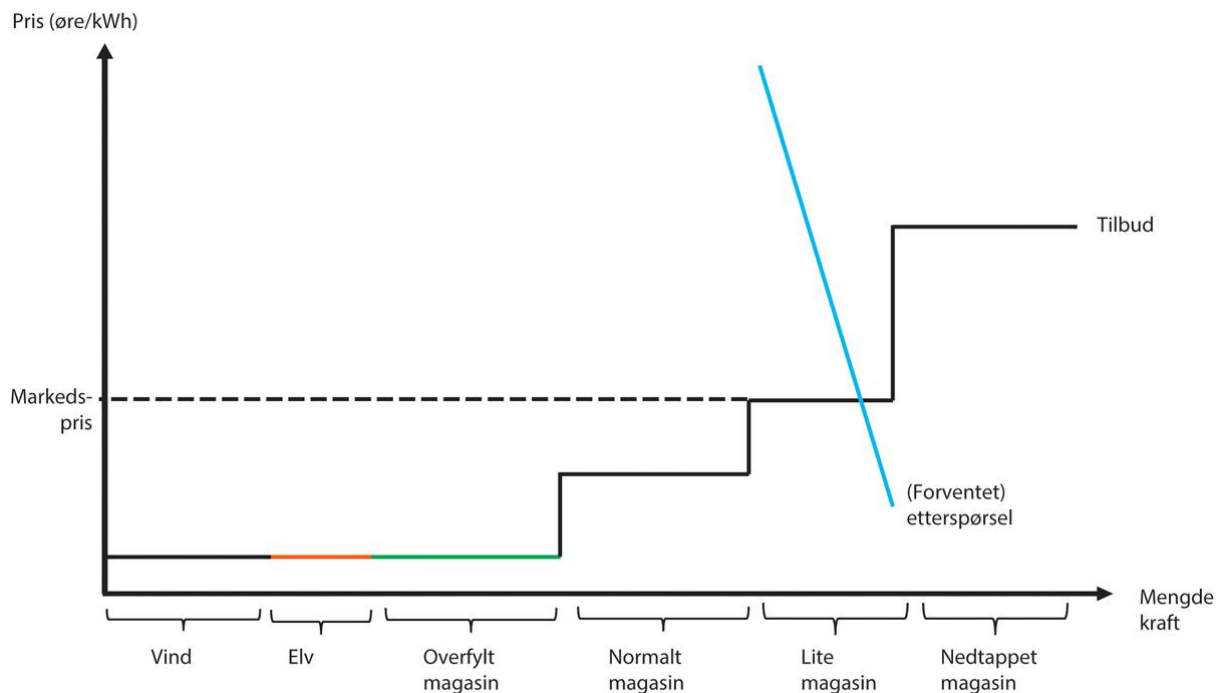


Figure 13.1 Price formation in an isolated Norwegian power market

Energy Commission.

Power producers based on energy from the sun, wind and water (which do not have magazines) must produce when the energy is available. They will therefore want to produce even at very low prices. For hydropower producers with magazine capacity, the situation is different. They can save the water (energy) if production has a greater value in the future (a water value) when the price is higher.

On the power exchange, the bids from all players are compiled, illustrated at the market cross in Figure 13.1. The price is set equal to the bid from the last unit required to meet all demand. If there is a lot of power with low costs, the price will be low. If there is little power at low costs, more expensive resources must be used and the price is higher. If there are bottlenecks on the boundaries so that it is not possible to transfer power from cheap areas to expensive areas, prices will be different on each side of the border. This is a system used in most markets with identical products, for example in a variety of commodity markets.

### 13.2 Pros and Disadvantages of the current System

Today's design of the power market has several advantages.

Such a system helps to ensure that the supply covers all demand. When pricing is based on the latest unit entering the market, it will just provide incentive to offer production in the market until the need is met. The system also guarantees that all profitable power is produced.

An organization that today also contributes to the mobilized producers with low costs, before producers with higher costs. For example, if there is little water in the magazines and thus scarcity of hydropower (if one assumes only a Norwegian market), a wind power producer knows that it is not the one who sets the market price. Then the most important thing for the wind power manufacturer is to have the opportunity to sell power. To ensure that it is chosen, it is best it can do to offer its power at a price equal to its own costs. Then it is guaranteed to be chosen in all cases where it is profitable to produce.

At the same time, the power system has several physical properties, which means that prices can be very high in situations with scarcity. Electricity must be largely produced when consumed, which means that the use of stock to smooth out prices plays a less role than in other markets. In other markets, the consumption side can also adapt by postponing their purchases - by forming queues. The power users' ability to adapt is not as large. All in all, it means that a wide range of technologies, with partly very different cost structures, sets prices in the power market.

High spot prices provide a significant redistribution, where some manufacturers achieve a large profit while the end users pay a very high price. This is precisely the situation we have experienced in 2022 in parts of Norway, in that southern Norway has had very high prices. At the same time, power producers have had a significant profit. Part of the profits accrue to the state through the basic interest tax for hydropower. Some power producers have also entered into agreements on price hedging for parts of the production, which means that they have received a relatively low price compared to the high price of the power exchange for that part of production.

Such a system can lead to large differences in prices, both across areas and over time. It can be explained by scarcity in certain areas or at certain times, and correspondingly much power available in other areas or at other times. Variations in prices will help the market clear in the individual area (the power does not go), but at the same time it challenges the legitimacy of the system. The difference in prices between Central Norway/Northern Norway and Southern Norway has been significantly in large parts of 2022, with prices close to zero in central Norway/Northern Norway for long periods and prices at times over NOK 5/kWh in the south at times -Norway. However, there have typically been small price differences in the period 1991-2021, and so it is quite unique what we have now experienced. Persistent, significant price differences between different parts of the country can help to weaken the system's legitimacy and support in the population. Persistent very low prices in some areas, in turn, can be a challenge if the power producers are not covered by their costs.

Another challenge is that a manufacturer with great production can get market power. This has been clear in connection with Russia's behavior in the gas market in Europe, which has also led to very high prices in the electricity market. Europe has few alternatives, and so far it has not been possible to satisfy all demand without deliveries of gas from Russia. When an actor gets a strong position, it can withhold production and thus force a higher price, or simply set a high price.

In the Norwegian power market, as in all markets, there is a need for rules that ensure that one avoids harmful utilization of market power. Both RME and the Competition Authority are monitoring the power market, including through a collaboration where they monitor the price movements in the market. The competition rules are enforced by the Competition Authority, and there is a ban on harmful cooperation and against the abuse of a dominant position. In addition, the Competition Authority can intervene against competitive mergers and acquisitions. After the Competition Authority decided to intervene for two acquisitions in the early 2000s, Statkraft-which is the largest manufacturer in the Norwegian market-has not implemented any major acquisitions in the Norwegian power market. At that time, the concern was that Statkraft after a possible acquisition could utilize market power in connection with bottlenecks between different areas. The Competition Authority has recently stated that there were examples of unfortunate behavior in the Norwegian power market in the years following the deregulation in the 90s, but that they have no indications that today's high electricity prices are due to violations of the Competition Act in Norway (Skjæveland and Søreide, 2022).

### 13.3 Challenges during today's crisis

Based on the high prices in the power market in 2021/2022, several questions have been asked about today's market design, and especially if it is true that the marginal manufacturer should set the price when much of the power generation has significantly lower operating costs.

If we go back a few years in time, a collapse was predicted in the power market sometime in the 2020s (Omland, 2018). With collapse, very low prices are meant during periods. The reason was that it was installed and plans for a lot of unregulated power on the continent, and especially the sun and wind power. When the wind blows it would be very high production and the price could go to zero. Today we experience the opposite, with very high prices for long periods. True, we see several examples of very low prices for a few hours with very high wind and solar power production, in line with what is predicted, but the average price over time has been high. There are several factors that can explain the current situation.

The main reason is that Russia has significantly reduced its deliveries to Europe, as discussed in Chapter 3. It hit the EU hard, as they had risen on Russian gas to secure their energy supply. Several other unfortunate circumstances have reinforced the effect of Russia's threading of gas deliveries. The shutdown of thermal power generation has proved difficult to reverse and there have been operating problems for nuclear power in France. Drought in Europe has resulted in reduced production, by the fact that boats have had trouble carrying coal to coal power plants on rivers that have little water flow, and nuclear power has had problems with cooling due to lack of water.

The remaining deliveries of Russian gas have been crucial to clearing the market, and to secure enough power to meet demand. Figure 13.2 illustrated how gas, which is used for the production of power, affects price formation in the power market in Europe today.

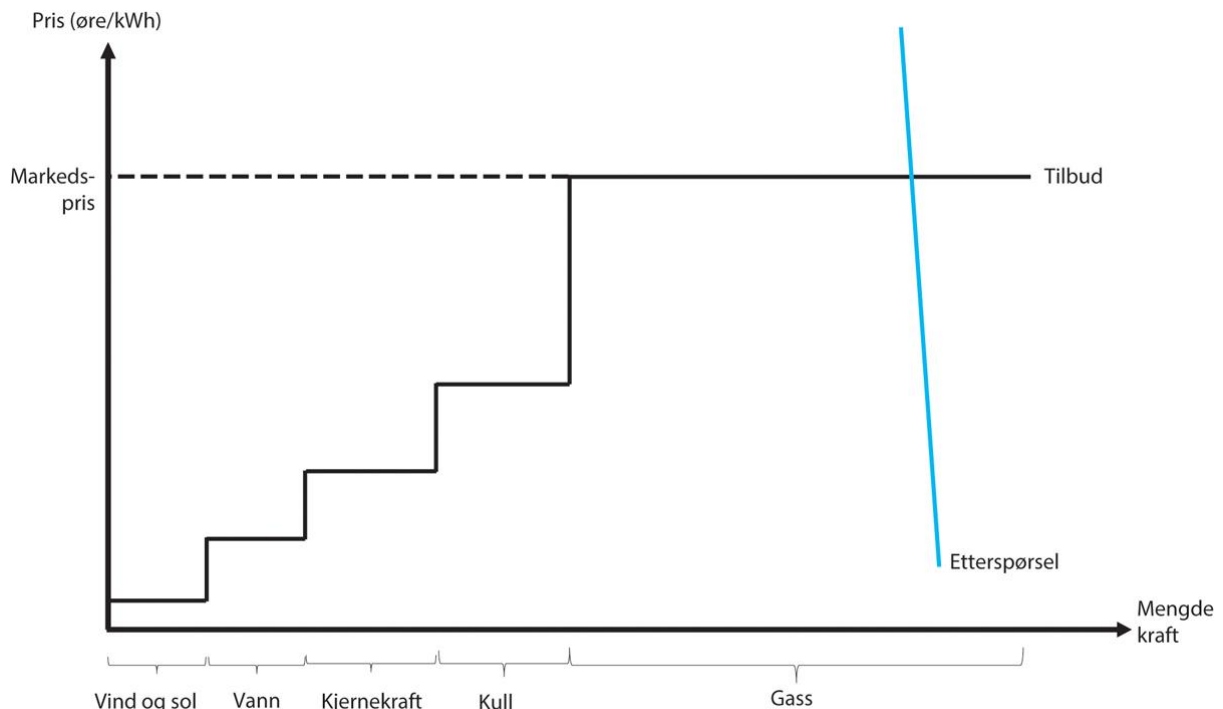


Figure 13.2 Price formation in the European power market  
Energy Commission.

The different energy sources have different costs. The market price set is based on the bid from the last unit entering the market. Today, the last unit is often produced using gas.

In the autumn of 2022, Europe is still dependent on Russian gas and imports of LNG (liquid gas) to clear the power market. In response to the need for gas, it is now being built that receives LNG. Increased storage capacity is also being built. Some of these plants may be clear already towards the end of 2022, but it will still take some time to increase the capacity significantly. Norway has increased its gas deliveries by 8 per cent, but it is also not sufficient to compensate for the loss of Russian gas. Thus, the gas price is determined by LNG at high prices and expectations of future gas access. Energy scarcity is a major challenge in Europe.

Norway is connected to the European market through power cables. The first cable was put into operation in 1960. As of the deregulation of the power market in Norway, and eventually in the rest of Europe, Norway, the Nordic and Europe have become closer connected both in terms of market and physically. Figure 13.3 shows several of the milestones in development.

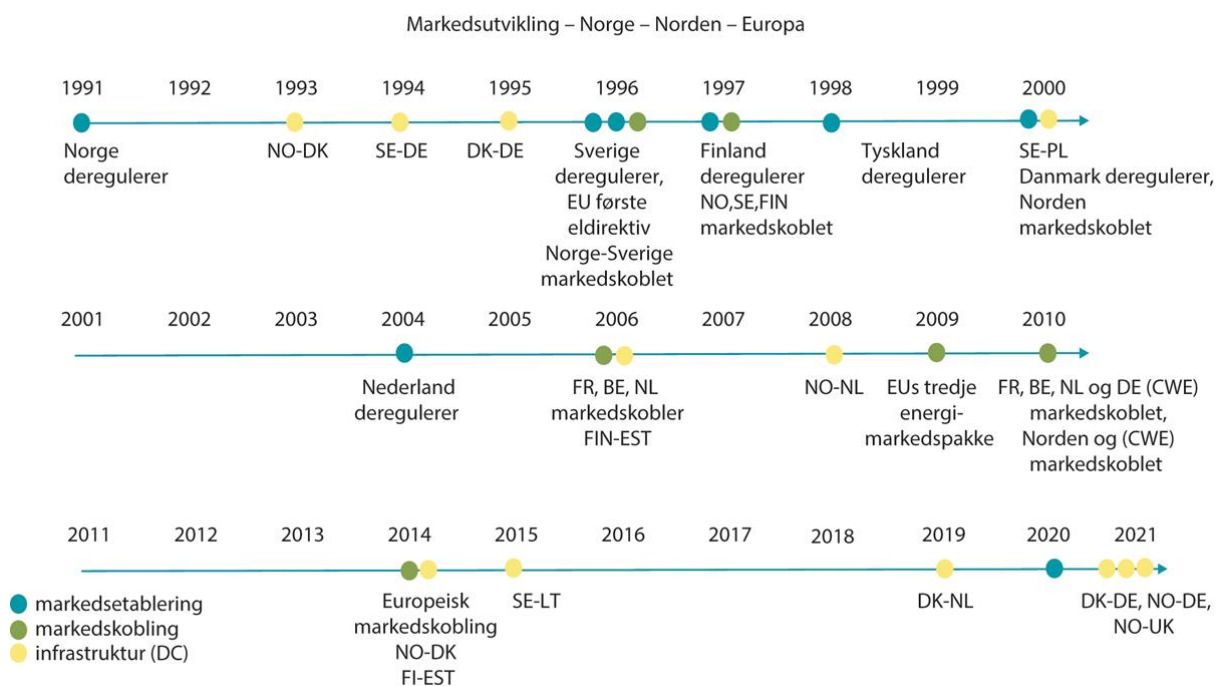


Figure 13.3 The development of the integration between the Norwegian Nordic and European Power System

Energy Commission.

From 1996, a joint Swedish-Norwegian power exchange was established, and thus a common market. The market has gradually been expanded, and we are now part of a European electricity market. At times, bottlenecks occur in the network between different areas, so there can be price differences between Norway and abroad. Figure 13.4 shows that the prices in southern Norway (NO2) have been co-watered with the prices in Germany and the United Kingdom for a number of years. In particular, there has been a close link with German prices.

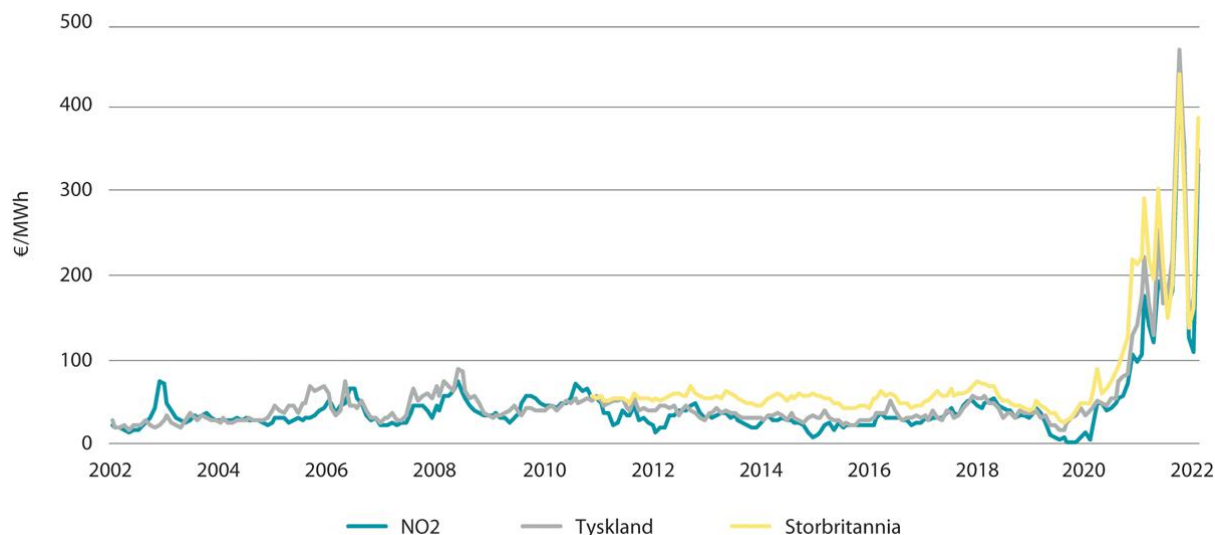


Figure 13.4 Price trend in Norway (NO2), Germany and the United Kingdom. 2002-2022 Statnett.

At the same time, Norwegian prices have been significantly affected by dry and wet years. In dry years, the price is often higher in Norway than abroad, while in wet years it is lower. For example, the price in Norway was significantly higher than in Germany in 2003. This was a dry year and the possibility of import was quite limited. By 2020, the price in Norway was very low as a result of wet years.

The capacity of the intermediate country compounds was significantly increased in 2021 at the opening of two new cables, respectively to England and Germany. In Figure 13.5 we have shown all the intermediate country compounds for Norway. The last cables led to the capacity of the intermediate country compounds increased by almost 50 per cent.





Figure 13.6 shows the price formation in the Norwegian power market, when we also take into account the link abroad. Norwegian power prices are determined by many different factors. The level of demand is largely affected by weather and season. Demand one summer day is normally lower than a cold winter day, illustrated by the two demand curves. Because demand has historically been little price sensitive, the demand curve is almost vertical. This means that high prices only result in a slight reduction in demand. However, the reduction in power consumption we have seen over the past year may indicate that at very high prices, demand is somewhat more sensitive than shown in the figure.

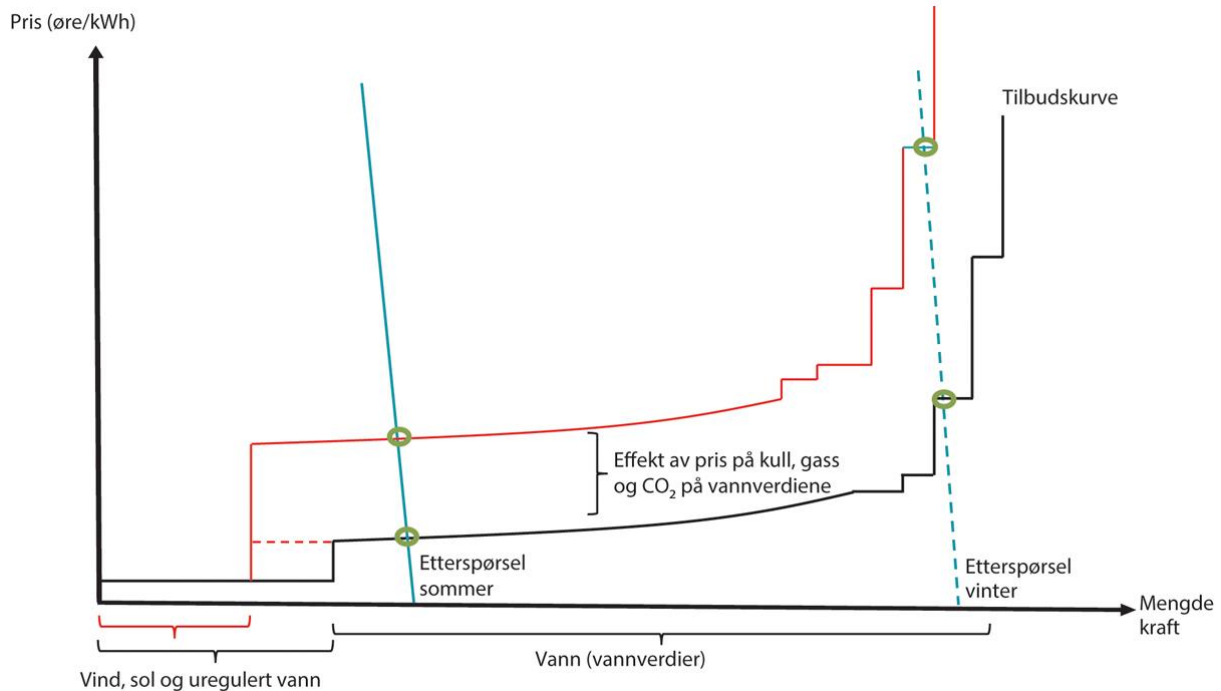


Figure 13.6 Norwegian power prices are affected by European prices

Energy Commission.

The offer basket can be illustrated as a multi-level staircase. At the far left and at the lowest cost is wind power, solar power and unregulated hydropower. This is production that is always offered at low/zero prices and is therefore used first. As production varies with the weather, the supply basket will be different in different weather conditions.

The price of coal, gas and CO<sub>2</sub> determines operating costs for power plants in Land Norway trades with. The varying cost affects Norwegian water values and therefore moves the middle part of the supply curve up and down. Magazine filling and inflow here at home also help to determine how hydropower is priced compared to power plants abroad.

The steepest part of the supply curve on the right represents top loads and their operating costs. Due to lower efficiency, top loads often have higher operating costs per unit produced than other gas and coal power plants. Although these are not found in Norway, they can also set the price here at times where we have too little effect in Norway to cover Norwegian consumption and at the same time have full exports.

The green circles, where supply and demand cross, show the power price. The power price can vary widely in time and between different price areas.

In Norway, a large proportion of end users have linked their power price against the price of the power exchange (spot price). Thus, high prices immediately affect the electricity bill for

households and can thus be unfortunate for consumers. On the other hand, periods of very low prices on the power exchange, which were the case throughout Norway for large parts of 2020 and in Northern Norway in large parts of 2022, will also immediately hit the prices of households and thus be beneficial for consumers .

An important lesson from today's crisis is that the close integration with the European power market makes us vulnerable to situations with energy shortages and high prices in our neighboring countries. Given the large element of spot price contracts for households and partly business, a crisis in our neighboring countries gives a fairly immediate effect on the prices Norwegian consumers face. Therefore, there is a need to make the system more robust. Both to dampen the prices for consumers and to secure our own security of supply.

### **13.4 Structural market reform in other countries**

The Norwegian power system is unique in the sense that it is already based on renewable power, mainly hydropower. In other countries, the power sector has to a small extent been renewable. At the same time as they discontinue power generation based on fossil energy, these countries must build a new power system to reach the goal of zero emissions. The transition from fossil to renewable production in these countries is dramatic. They change from a system of stable supply of power (thermal system) to a system where they rely on unregulated power such as solar and not least wind power. This can create large price fluctuations from day to day, depending on whether it is sunny and wind.

In July 2022, the British authorities sent a note as a play to a public debate on how to organize the market (Ministry of Business, Energy & Industrial Strategy, 2022). The EU, for its part, plans to submit a proposal for a structural reform during the winter of 2022/2023.

The major restructuring towards renewable production that we see in The EU and the United Kingdom emphasize the need to assess how the large investments in unregulated renewable power should be financed. Part of the renewable power, such as wind power, has a limited number of hours it can produce. If the wind power producers get paid in the spot market, the price can be low, as a lot of production will enter the market at the same time. This is the reason why there are already long -term contracts today where wind power producers' future revenues are fully or partially disconnected from the daily price of the power exchange. Some of the contracts have been signed on purely commercial terms, so -called Power Purchase Agreements (PPA), between wind power producers and buyers. In addition, there are a number of examples of so -called differential contracts, especially in the UK. A variant of the differential contracts means that the wind power producers compete to develop with the lowest possible support from the authorities. Through long -term agreements, the state relieves the manufacturers of the risk they would otherwise have to take on their own. It is an example of public support that can help realize investments in renewable power at the lowest possible cost to society.

The transition towards a large proportion of unregulated power will lead to large variations in power generation from day to day and from hour to hour, especially depending on whether it is blowing or not. There is a need for a market design that can handle such fluctuations, and then one must have a price formation that corresponds to what one has today where the market is cleared every hour (or more often). This ensures that power is available, but at the same time it can provide large price fluctuations that it is not desirable to fully overturn the end users. For this reason, in both the EU and the UK, there is a debate on a possible future top price system that will facilitate investments in renewable power, offers of stable prices for end users and market clearance.

There are several possible systems with two prices in the market. Such a possible system that has been discussed for the power market is a separate market for unregulated power (AS Available) and one for adjustable power (ON Demand). Typically, some manufacturers will sell in one market, and other manufacturers in the other market. Buyers can then choose to buy from the first market (unregulated power), where there is lower security of delivery, and then, for example, in the form of a fixed price contract. Alternatively, they can buy from the other market (adjustable power), where the security of delivery is higher, but at a price that is set like in today's market system. In the UK's consultation note, this system is briefly mentioned. They point to several possible benefits of such a system:

- The price in the unregulated power market can be disconnected from the price in the market for adjustable power. If one succeeds, one will avoid pricing and large price fluctuations from the market for adjustable power.
- It can reveal the demand for flexibility and it can reveal how much customers are willing to pay for safe delivery in the market for adjustable power.
- It will contribute to flexibility on the demand side by allowing customers to shop in both markets.
- It can potentially help support investments in renewable power, as the market for unregulated power provides a greater opportunity for long-term contracts and thus predictability.

At the same time, the consultation note is pointed out on several possible disadvantages with such a system:

- It is not clear how such a system should be designed. Among other things, the interaction between the markets can be a challenge, including the extent to which one succeeds in disconnecting price formation in the markets apart.
- It is an open question what added value such a brand new system will produce. Many of the benefits will be due to consumers facing more fine-masked prices, more specifically more pricing of flexibility. More flexibility can be achieved in ways other than through a division of the market.
- A two-price system can lead to reduced competition, because there may be fewer players in each of the two markets than in a common market.
- A transition to a two-price system is a challenge in the short term, as this can lead to investments being put into which pending a new system.
- A two-price system can create challenges for consumers if such a system provides a more complex and unclear market.

The consultation note briefly appears to a different and less drastic change in market design in the same direction. However, it is even more uncertain to what extent one will succeed in disconnecting the price in the market for unregulated power from the price in the adjustable power market. It is also pointed out that it is uncertain whether the incentives for the development of new power can be achieved through PPOs (Purchase Agreements), that is, long-term agreements between power producers and customers.

Furthermore, it is emphasized in the consultation note that the top price model is an untested, conceptual approach with several possible disadvantages, as mentioned above.

In the EU there is a similar debate, but at an even earlier stage than the one in the UK. Greece has proposed a two-price system as a possible solution to today's energy crisis. The European Commission has, in its hearing on market design, in a note at a completely overall level, mentioned a possible solution with a two-price system (non-paper, 2022). It is highly uncertain how such a system actually becomes, as so far there is no detailed description of the

proposal. The proposal must be seen in the context of the structural reform for the EU current market, which the European Commission is likely to present at the hearing in the winter of 2022/2023.

### 13.5 Trade abroad

Norway is linked to the other Nordic countries, Germany, the Netherlands and the UK through foreign connections. An important reason for linking us abroad has been to strengthen security of supply. This rationale also stands today, although we now see that in situations of energy scarcity in our neighboring countries there may be challenges in importing power. The foreign connections make it possible to import power this year with little inflow in Norwegian water reservoirs, and export in other years. The variation in inflow from year to year is shown in Figure 13.7, where it is seen that the inflow in 1991 was 79 TWh greater than the inflow in 1996.

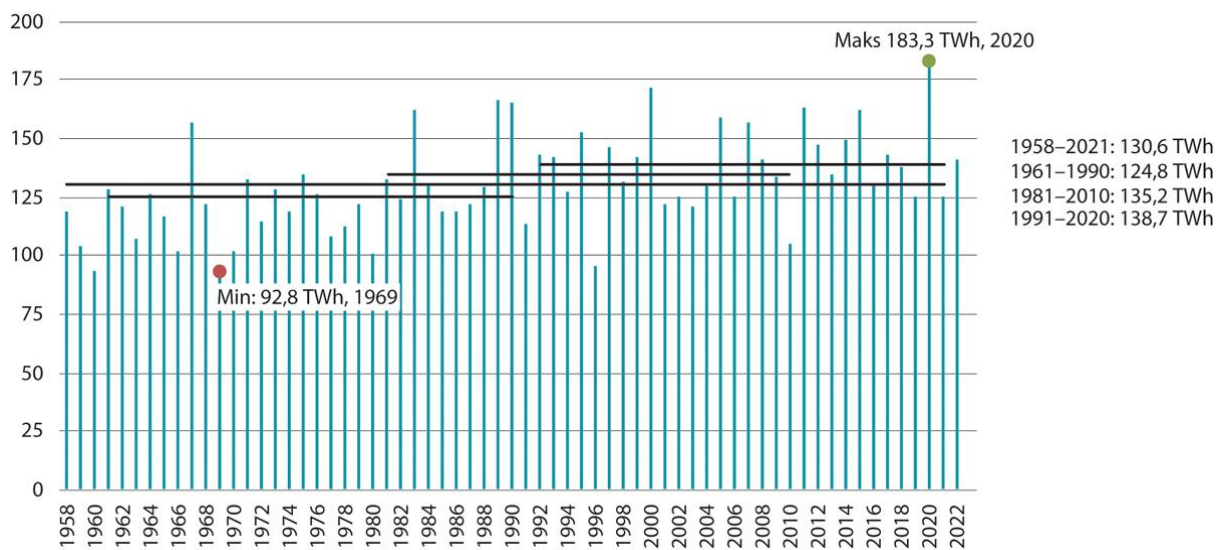


Figure 13.7 Variations in inflow from observed water flow in Norway. 1958–2022

NVE.

Climate change means that one can expect even larger variations in the future, see Chapter 8. Thema's forecast shows that the variation can be up to 100 TWh between dry years and wet years, see Chapter 11. If Norway should have been self-sufficient, one had to have expanded sufficient power generation to cover the need in dry years. This will provide a large surplus of power in all other years, with low prices. There will be little profitable with power development and energy efficiency. At the same time, the low prices will attract new industry and in isolation to consumers as well. However, it will not be possible to maintain a power balance that ensures us in dry years without large subsidies for new development. Much power can go to play in such a thought closed power system characterized by hydropower. Production in wet years can be so great that the price is almost zero, and there can also be water that is not used to produce power.

Foreign cables allow us to import in dry years, thus avoiding expanding such large production, and at the same time exporting in wet years when we have a lot of power available. The foreign cables are also used for more short-term power trade, where the Norwegian hydropower system has so far traded with the thermal system that surrounds us. A thermal system - such as nuclear power and coal power - will typically produce a stable quantity over the day. Hydropower, on the other hand, is flexible and can turn on and off at short notice. The interaction between the two systems led to Norway exporting abroad during

the day when the outside world needed more power, and imported at night time when the outside world produced more than demand. Consequently, trade arose that both parties earned.

With a transition to renewable energy in other countries, we face a completely different interaction with the countries around us. But that does not mean that there is no longer the potential for trade that can serve both parties. Norway will continue to be able to import power in dry years and export power in wet years. There is also potential for short-term exchange. This can be illustrated using Figure 13.8, where the arrows illustrate the power flow.

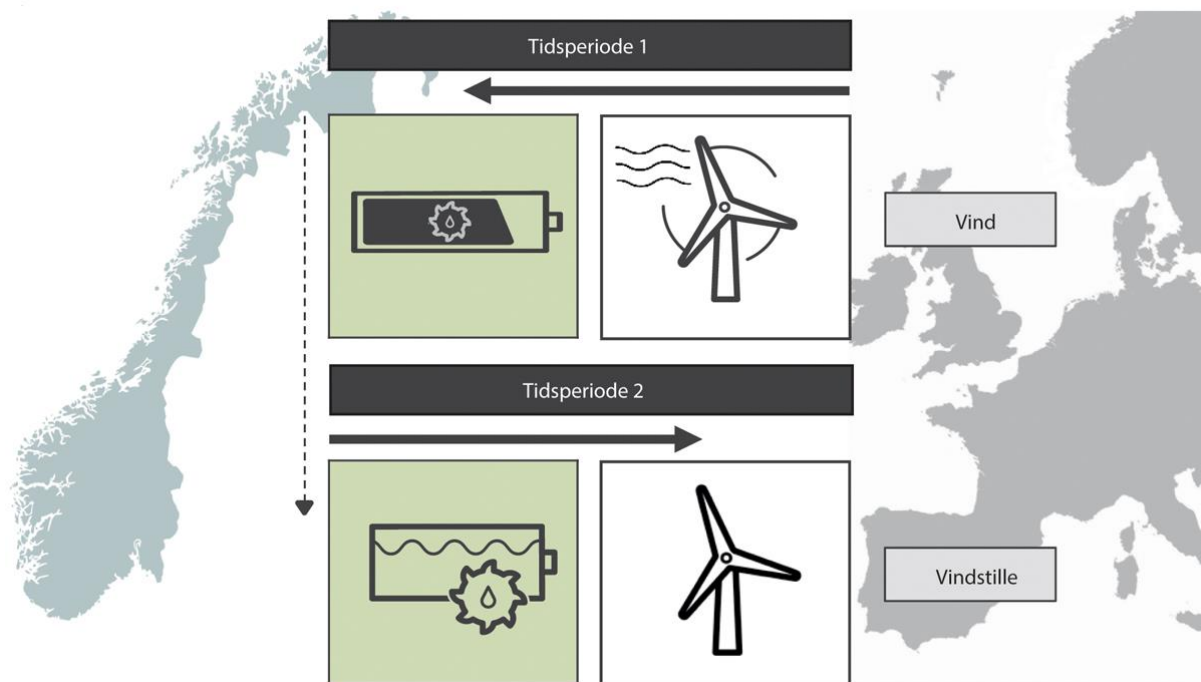


Figure 13.8 Illustration of short-term trade abroad

Energy Commission.

Let's consider two periods of time, where in one period it blows on the continent (time period 1) and in the other period do not blow on the continent (time period 2). When it blows abroad, there will be large production from wind power, and the price will be low. Then there is the potential to import to Norway at a low price, and even save on your own water. The water can be saved for the next period when it does not blow abroad.

It will not always be the case that Norwegian consumers get as low a price as abroad when it blows. Imports during periods of a lot of wind means that water can be saved and thus used at a later date. Then it is conceivable that the price in Norway during the period of import is higher than the price in our neighboring country because hydropower producers find it profitable to save on the water at a later period of higher price. When water is saved and used for production later, imports at a low price will contribute to lower price in other periods as well. In this way, imports at a low price will contribute to a lower average price in Norway, although the price at the time of import is higher in Norway than abroad. Competition will ensure that water is disposed of in such a way that prices are fully or partially equalized. This is because in a competitive situation, a manufacturer will want to move its production in the direction of the period at high price. This is beneficial for the consideration of the disposal of

the magazines, as water is saved for use during periods of scarcity (Bye, von der Fehr, Riis and Sjørgard, 2003).

### **13.6 Market Design and Foreign Trading Forward**

There will be major changes in the power system in the years to come, partly as a result of the transition to more renewable energy in response to the climate crisis and partly in response to the ongoing energy crisis. This can be of great importance for the organization of our power trade with abroad, and thus also for the Norwegian power market. Given the great uncertainty of what will happen in the countries around us in the coming years, it is not advisable now to detail a unilateral change in the regulation of today's Norwegian power market. We will therefore only outline some challenges in the future, and in what direction the system should be changed. Our recommendations on what measures should be taken are given in Chapter 1.

It may be appropriate to distinguish between further development of the Norwegian system as such, and further development of the interaction with abroad.

#### **13.6.1 Market Design in Norway Forward**

As briefly explained above, major structural power market reforms are discussed in the countries around us. However, they have completely different challenges than what we have in the Norwegian power system. They will discontinue their existing fossil production and must build a power sector that will largely be based on unregulated power such as solar and wind power and new flexibility solutions. In Norway, we build on what we have, largely adjustable hydropower, where new unregulated power becomes more a supplement than the very foundation of our system. So even though it is useful for us to learn from other countries' experiences, we must take into account the unique characteristics of the Norwegian power system when we are going to make any changes to the regulation of our power market.

Although hydropower in the future will be central to the Norwegian system, wind power will have an increasing proportion of total production in Norway. On the demand side there are also major changes, for example, consumers charge electric cars smartly and in other ways adapt their consumption to price variations throughout the day and throughout the week.

The large fluctuations in both the short and long term require a system for connecting the cheapest power source first at any time, and to mobilize enough power to clear the market. The experience of the Energy Act has shown that a system of a power exchange in the wholesale market helps the market to be cleared, and that it is the producers with the lowest costs that actually produce. The experience with wind power so far is good. When wind is reported the next day, the wind power producers offer the power exchange so that the power is sold in the market. The system thus ensures that those who produce at the lowest cost are mobilized. When wind power is produced, it is possible to withhold water in the magazines that can be used in later periods. In this way, no more renewable power - which is unregulated - will in itself speak to change today's regulation of the power market. Rather, on the contrary, today's system provides a good interaction between wind and hydropower. The Norwegian power system with adjustable hydropower that interacts well with wind power will still be unique, when our neighboring countries have a transition to a system with a much larger proportion of unregulated power.

With changed consumption and production patterns, we must emphasize renewing and developing today's market system. Among other things, it is important to develop and utilize more flexibility on the consumption side. Mechanisms and storage solutions must be designed that make it easier to move power consumption at times where there is no great scarcity. Power consumption must be reduced more when prices rise than is the case today.

Chapter 9 describes changes in the current system that will increase the flexibility of the consumption side, while flexibility on the production side is mentioned in Chapter 10.

Today's crisis is mainly an energy crisis. An important lesson is that the power balance in Norway is of great importance for security of supply, and a clear indication that the development of renewable power is crucial to avoiding similar crises in the future. Combined with increased flexibility on the consumption and production side, increased power generation will reduce the risk of dramatic impact of a new crisis in the Norwegian energy market. Precisely such measures can help consumers, both households and business, secure power at an acceptable price in the future. But a dramatic crisis with a great lack of energy can mean high prices in the future as well. Then it is important to learn from the experiences of today's crisis, and the measures that have been implemented. For example, there is now a discussion of possible restrictions on the magazine filling to contribute to security of supply, similar discussions in the follow-up of the strained power situation in the winter of 2002 and 2003.

Norwegian households are, as explained above, more exposed to fluctuations in power prices than in most other countries, because many have a electricity agreement where the price is directly related to the spot price in the wholesale market. In this way, there is an opportunity for households to a greater extent enter into long-term agreements if they want greater predictability on the electricity bill. At the same time, flexibility in consumption helps to remedy both energy and power shortage.

If consumers in today's system are to be offered long-term agreements on commercial terms (ie not subsidized), it will not mean lower average price to consumers. A solution with a two-price system along the lines discussed, among other things, in the UK (see description above) may mean that larger power users have long-term agreements linked to, for example, producers of wind power and to a greater or lesser extent are decoupled the daily spot price. To what extent this is possible in practice, how it will work in the Norwegian system and whether it provides any benefits for consumers and society, it is too early to decide.

A very central question in the future is the construction of sufficient renewable production capacity. Part of the renewable power, such as wind power, has a limited number of hours it can produce. If there is a lot of wind power, it can also mean that the price it gets paid in a regular spot market is relatively low since much production enters the market at the same time. Due to large elements of adjustable hydropower production in Norway, prices in the future are expected to be more stable than in countries where wind power accounts for a large proportion of production. For this reason, wind power can achieve a better price in Norway than in other countries. Several of the wind power projects are funded using PPAs, which is a long-term power sales agreement. It ensures predictability and thus better financing opportunities for wind power producers. However, it is important to consider whether there is a need for new mechanisms that can ensure the development of sufficient renewable power in the future. This is especially relevant for offshore wind, and especially floating offshore wind, which has a significantly higher investment cost than onshore wind power. This can be done, for example, by so-called differential contracts. This can help relieve risk and at the same time contain an element of state support.

### **Box 13.1 Differan contracts**

A differential contract usually means that the state enters into a long-term agreement with a developer, for example a developer of offshore wind, where the developer is guaranteed a fixed price in a specific period. One of the benefits of long-term contracts is that through such contracts, the state can directly control the number of GW that is being expanded and



the pace of the development. In addition, the risk, and thus financing costs, can be significantly reduced for the projects, as the contracts provide secure revenues (make the projects so-called "bankable").

A differential contract means that a guarantee price is set (Strike Price) per kWh, which the developer receives for a fixed period. A two-sided differential contract means that if the price in the market is lower, the developer will receive a support amount, and if the price in the market becomes higher, the state will receive an amount corresponding to the difference between the guarantee price and the market price. One possibility is that the developer receives the income from a proportion of his production through the guarantee price, and that the income of the rest of the production is marketed.

The guarantee price may be set administratively or through competition. The UK has in a number of projects, including in the bottom for offshore wind, used differential contracts, where the developers offer the guarantee price. Such a system provides incentives to compete on which guarantee price one will offer. The experience from the UK is that such competition over time has helped to lower the guarantee price, and thus the costs.

If differential contracts are used to ensure a fixed price regardless of the spot price, winnings will arise when the spot price is above the guarantee price and a cost when the spot price is lower than this price. Overall, differential contracts can lead to a gain for the state (if the spot price over time is higher than the guarantee price) or it can lead to support from the state of the developer (if the spot price over time is below the guarantee price). Alternatively, gain/cost can be brought to consumers as a surcharge/deduction in the electricity bill. However, what price the developer is willing to bid to expand (the guarantee price) will not be affected by whether the gain/cost will be continued to the consumer, and thus the cost of society will not be affected by who eventually pays the bill (or gets the gain). In the EU, it is discussed to introduce differential contracts to finance electricity support for consumers because it is expected that the power price level, based on the marginal pricing principle, will be above the amount of support necessary to trigger investments in new renewable power generation. In the UK, in many cases, gain/cost is continued to consumers.

[Box End]

An alternative to differential contracts is direct investment support. The latter will typically be more suitable for immature technologies. This could be pilot and demonstration projects, where the technology risk is great and it is uncertain what production the technology will lead to (Menon, 2020), (Oslo Economics, 2022).

A power system with much adjustable hydropower is dynamic in the sense that water can be moved from one period to another, and it is very demanding to detect whether the manufacturers' behavior is harmful from society. It is important that the structure of the market is such that there is as little room as possible to utilize market power. In the report "Power and Power" (Bye, von der Fehr, Riis and Sørgard, 2003), it was concluded that the concentration in the Norwegian hydropower sector should not be higher, as it could lead to competition problems. It is natural that it is again further investigated whether the structure of the power industry ensures well-functioning competition, in a situation where the system is changing by, among other things, an increased proportion of renewable power and where Norwegian adjustable hydropower will play an even more important role than before. As described above, competition is important to help water be disposed of in a favorable way for society. Major structural changes may not be needed, but we should be precautions and consider possible measures before there may be situations with harmful utilization of market power. Furthermore, it is important for the legitimacy of the system that one can explain how

competition works in this market, regardless of whether you finally make structural grips or change the monitoring.

### **13.6.2 Trade abroad forward**

As the power market is regulated now, it is the hourly rates on the power exchange that are crucial for trade between land. This is a trade regime that has been gradually developed over several decades. As explained above, such a system makes us vulnerable to the scarcity of power in our neighboring countries, with high prices as we have seen in southern Norway in 2021 and 2022 as a result. However, under more normal circumstances, with plenty of power available in our neighboring countries, such a trade regime can provide gains that also benefit Norwegian consumers.

It is difficult to predict how the energy situation is in our neighboring countries in the medium and long term. One possible scenario, which was ahead before the energy crisis 2021/22, was that for long periods there will be a lot of power available in our neighboring countries. In that case, it is conceivable that Norway will import very cheap power for long periods and reduce the need for development in Norway. Long periods of very cheap power in our neighboring countries may be due to the fact that more power generation has been developed than what is in demand. The price that is realized in their markets can then be so low on average that it is difficult to achieve at least as low an average price in the Norwegian power market.

Such a development, with little or no power development in Norway in the future, is problematic for several reasons. Without power development in Norway, the power surplus will be reduced and in the worst case we can have a power deficit. NVE estimates that the greater the surplus Norway has, the more likely it is with lower prices in Norway than in our neighboring countries. Power development and thus maintaining our surplus of power can thus contribute to competitive prices in the Norwegian market. At least as important is that without a power surplus in the normal year we will put ourselves in a very vulnerable situation if our neighboring countries in the future have a lack of energy in the future.

Another possible scenario is that the operation of the intermediate country connections is less linked directly to the daily prices of the power exchange. Seen from our neighboring countries, they want access to effects during periods when it does not blow in them. They can then pay for just this, and they may be entitled to import when such a need arises regardless of the daily prices in the markets. At the same time, from a Norwegian standpoint, there may be a desire for access to cheap wind power. It may also be appropriate to access their flexible power, to the extent that they have built it up, when we are in a dry year. Can such a trade regime, which differs from today's trade regime, help to decouple the two markets in the two markets, and is it beneficial that this happens? How do we ensure national control over our water resources, not least in dry years, if it is the case that a neighboring country gets the option to import power when they themselves are most in need of it? We do not know of any thorough analysis of the advantages and disadvantages of such a scenario, but now that there are ongoing reforms in the UK and the EU, among others, this and similar scenarios may become relevant.

In general, it is in Norway's interest to act both in the short term and in the long term. In the future, more analysis environments are expecting a tighter power balance in Norway. If it occurs, it will mean a greater need for imports in dry years. At the same time, there may be gains associated with exports in wet years, including Would we avoid trapped power and very low prices during certain periods. The short -term trade can also be beneficial for

Norway, as we can import one day it blows on the continent and export one day it is quiet on the continent.

Similarly, it is in other countries' interest to trade with us. If Norway has net power surplus in a normal year, we will be able to offer relatively affordable force to the outside world. Furthermore, Europe needs to sell large amounts of power when it blows, and the need for imports when it does not blow. In this way, there is potential for a win-win situation in trade abroad.

However, today we do not know what the trade regime will look like in a few years. Given possible changes in the system, it is important that Norway promotes its own interests and conveys solutions that we as a nation are best served with. As a rule, trade will be in both parties' interest. This means that Norway has a common interest with the outside world to come up with good solutions that serve both parties. In today's geopolitical situation with war in Ukraine and Russia's threading of gas deliveries to Europe, there is extra good reason to be explicit that together we must agree on any new conditions for trade. Then it is important that other countries also follow the common rules that we follow. Among other things, it may be in Norway's interest that the countries we trade with also create price areas in our own country and at the same time do not limit the power flow from the outside world to Norway.

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