Summary in English

The Norwegian Nuclear Commission's assessments and recommendations

1 Background

The Commission's mandate can be summarised in two main questions:

- What role can nuclear power play in the Norwegian energy system?
- What would be required if Norway were to introduce nuclear power?

A key task for the Commission is to establish an up-to-date knowledge base for assessing the introduction of nuclear power in Norway. The mandate calls for a broad review and assessment of various aspects of a possible future establishment of commercial, industry-driven nuclear power in Norway. Key topics to be examined include the suitability of nuclear power for the Norwegian power system, the state of research and technology development in nuclear power, costs, and consequences for public authorities and private actors, land-use and environmental impacts, waste management issues, nuclear safety, nuclear security and safeguards, and emergency preparedness and competence needs. In addition to discussing the advantages and disadvantages of nuclear power, the Commission shall describe the current regulations and the need for regulatory development. On this basis, the Commission shall provide an overall assessment, evaluate economic ripple effects, and highlight ethical aspects and the importance of societal acceptance.

The background to the appointment of the Commission is that the energy transition and technological developments have revived nuclear power as an option to ensure stable access to power in several European countries. The report focuses on the role that nuclear power can play in Norway's power supply. Several studies and analyses forecast increased power consumption and, thus, a need for emission-free power production to meet the climate policy targets. Nuclear power has become part of the Norwegian energy debate, and plans for development have been put forward. The last time nuclear power was assessed as an option for Norway was in Official Norwegian Report (NOU) 1978:35 A *Kjernekraft og sikkerhet* (Nuclear Power and Safety, available in Norwegian only). In 1986, the Norwegian Parliament (the Storting) stated that 'nuclear power is not an option for Norway's energy supply' (Innst. S. No. 2018 – 1985–86).

The Commission's assessments are based on a broad Norwegian and international knowledge base spanning several disciplines. The report draws from up-to-date knowledge and experience from other countries regarding technology, safety, radiation protection, emergency preparedness, environmental impact, costs, international regulation, competence, economics, the power market and the power system, law, and ethical and social science issues. The premises from the various disciplines are assessed in context, and together they form the basis for the Commission's assessments of the role of nuclear power in Norway.

2. Technology status, costs, and supply chains

Nuclear power plants currently being built or under consideration worldwide are based on established technology. Today's technological landscape can be divided into three main categories: large light water reactors, small modular reactors (SMRs) and advanced modular reactors (AMRs). Large light water reactors are technologically mature and account for the majority of current deployment. Most nuclear power plants in operation and under construction use low-enriched uranium as fuel and light water as a moderator and coolant.

Small modular reactors (SMRs) are nuclear power plants with new designs and are primarily based on established technology. Whereas development previously moved towards ever-larger reactors to realise economies of scale, SMRs – typically in the 50 to 300 MW range – have been introduced as alternative ways of designing and constructing smaller nuclear reactors. Modularisation means that key components can be standardised and factory-manufactured before being assembled on site. The aim is to reduce costs and shorten the construction period so that market revenues can be realised sooner. There are over a hundred different SMR designs under development. At present, only a handful of SMRs are under construction, and module production has not been established on an industrial scale. Even the most mature concepts are in an early commercialisation and regulatory phase.

SMRs currently being planned are typically sited together within the same area, often in connection with existing nuclear power plants. SMR technology can offer increased flexibility, easier integration into smaller markets, and potentially lower financial risk. By building several SMRs at the same site, economies of scale can be realised associated with collaboration models, workforce and competence, and the infrastructure required around a nuclear power plant. At the same time, the development of power plants based on large-scale reactors is also moving towards increased modularisation to reduce costs. Therefore, it remains to be seen whether the benefits of modular development of smaller units can outweigh the economies of scale that still apply to large reactors.

AMRs are at an early stage of development, and the technologies are less mature than light water technology. AMR technologies are characterised by the use of alternative coolants such as supercritical water, gas, salt, or metal, which can provide significantly higher operating temperatures than water. This results in higher thermal efficiency and can reduce waste volumes or open up new applications such as hydrogen production. At present, there is little to suggest widespread commercial availability within the next few decades. Thorium, of which Norway has large reserves, is a relevant fuel source in some of the designs.

The capital costs associated with recently completed large-scale nuclear power plants in the United States and Western Europe have been substantial. Nuclear power plants that have recently been completed, or that are under construction, in the United States, France, the UK and Finland have become far more expensive than planned and have been significantly delayed. There are several reasons for this, including the fact that few nuclear power plants have been built in recent decades, and that several projects have commenced construction based on new and incomplete reactor designs. In other countries and regions, the cost of new large-scale reactors has been lower, such as in the United Arab Emirates, South Korea, or China.

The capital cost for new large-scale reactors and SMRs currently under construction amounts to several hundred billion Norwegian kroner. The total capital cost for a 2 000 MW nuclear power plant with two large-scale reactors is estimated at between just over NOK 200 billion and around NOK 350 billion, with construction costs accounting for more than half the amount. Estimates for the construction of equivalent SMR capacity are in the same range. Fuel, operating and maintenance costs are additional.

Financing costs weigh heavily in the nuclear power equation. High capital costs, long construction periods and, in many recent cases, significant delays result in high financing costs and high financial risk. We are not aware of any nuclear power plants currently planned or under construction in Western Europe that do not receive state aid in the form of subsidies or risk mitigation.

Learning effects resulting from increased global deployment and the development of new solutions and designs may lead to lower costs in the future. Experiences from China indicate that costs can be reduced through a consistently high deployment rate and standardisation. In the United States and Western Europe, it will take time to develop competence and renew supply chains following a long period of limited new construction. The experience from the most recent nuclear power plants built in our part of the world shows that costs have risen. Increased standardisation of both reactor design and safety requirements is an important factor for benefitting from economies of scale and learning effects that could reduce costs in the future. Cost trends for nuclear power are influenced by many different factors, which makes it particularly difficult to predict how significant the learning effects might be.

Investments to ensure safety, among other things, have enabled some nuclear power plants to extend their operating licences to 80 years. Originally, nuclear power plants were typically built for an operating period of 40 years (newer plants for 60 years). However, the operating period can be extended through relatively extensive investments. Investments in lifetime extensions are influenced by how the plant was originally planned and its operating history, and are a commercial decision based on profitability assessments.

Nuclear power development involves very large and complex projects that place high demands on project management, coordination, and both specialised and general technical expertise during the construction phase. The construction involves several thousand people over several years, both on site, at suppliers, and within project organisations. Projects of this magnitude are often prone to delays and overruns. Norway has experience with, and developed competence from, large oil and gas projects that may be relevant in this context.

Several links in the international supply chains for nuclear power plant fuel are concentrated among a small number of suppliers. Uranium mining is dominated by Kazakhstan, Canada and Australia. Enrichment is concentrated among four companies: Rosatom (Russia), Urenco (the UK, the Netherlands and Germany), Orano (France) and CNNC (China). Fuel production takes place in a number of countries, including several in Europe.

*The concentration of the supply chains poses a risk of long lead times, bottlenecks, and limited competition***.** The range of actors and the supplier concentration in parts of the supply chain mean that both prices and access to nuclear fuel can be affected by international conditions. As of today, no economically viable uranium deposits have been identified in Norway, and it is unlikely that developing national supply chains for these inputs will be an option. Therefore, the construction of nuclear power plants in Norway will involve long-term import dependency and vulnerability to supplier concentration. Given these vulnerabilities, it is important to establish long-term and secure fuel supply agreements. Major reactor suppliers also hold strategic positions in the market. Only a handful of countries have industrial clusters with the capacity and certification to produce the largest and most demanding components, such as reactor pressure vessels.

Nuclear power generation produces radioactive waste that requires proper management and disposal. The main objective of managing waste from nuclear power plants is to protect people and the environment from the adverse effects of radiation. As a general rule, radioactive waste and spent fuel shall be managed and disposed of domestically. In addition, spent fuel contains plutonium, which can also be used to produce nuclear weapons.

Spent fuel must be disposed of in stable geological formations for 100,000 years to ensure it does not harm people or the environment. Spent fuel is placed in interim storage for several decades before being moved to a disposal facility. Deep geological repositories with multiple barriers isolating the fuel from the outside world are the internationally recommended long-term solution for the storage of spent fuel. Establishing a disposal facility requires extensive institutional development, robust financing arrangements and systems that can be operated across generations. The world's first disposal facility is scheduled to come into operation in Finland in 2026. After around 100 years of use, the disposal facility shall be backfilled and sealed. The disposal facility is located more than 400 metres deep in stable rock. Construction started in 2004. In Sweden, construction of a similar disposal facility began in 2025. Other nuclear energy countries are at various stages of planning and investigating sites for the disposal of high-level radioactive waste and spent fuel. The construction of such disposal facilities is characterised by high capital costs and economies of scale.

It is common to distinguish between low-level, intermediate-level, and high-level radioactive waste. Spent fuel accounts for only a small proportion of the volume of radioactive waste from a nuclear power plant. Nuclear power production gives rise to other types of radioactive waste, which must also be disposed of safely. Safe management involves, among other things, planning coherent waste streams from the outset, minimising waste volumes, incorporating barriers into transport packaging and storage containers, setting requirements for compliance with international standards, and ensuring approval on the basis of up-to-date safety analyses, documentation, transparency and funding. Waste management requires the development of competence and capacity among the authorities and stakeholders involved. International peer reviews and the exchange of experience across countries provide an important safety net for ensuring the quality of processes and solutions.

The decommissioning of nuclear power plants is a complex task that requires systematic and long-term planning and regulation. Decommissioning nuclear power plants shall ensure that the site is prepared for safe future use. This process encompasses planning, demolition work and waste management. Key elements are: (i) preliminary and final decommissioning plans, including financing; (ii) an established waste stream and interim storage solution for spent fuel; (iii) phased planning for potential geological disposal; (iv) competence development and the building of industrial capacity in decontamination, dismantling and characterisation; (v) release of the site for alternative use; and (vi) structured dialogue with stakeholders to ensure legitimacy and predictability in the process. Decommissioning must be planned already at the licence application stage for the nuclear power plant. In order to commence effective decommissioning of a nuclear power plant, the fuel must be removed from the reactor, either to storage facilities at the plant, to a centralised storage facility, or to a disposal facility.

Waste processing, and in particular the construction of a disposal facility, represents significant fixed costs that are often shared across several nuclear power plants. Calculations and experience from Sweden and Finland show that a national nuclear power programme must be of a certain scale to ensure that the unit costs associated with waste processing and disposal facilities do not become disproportionately high. In the nuclear energy countries examined by the Commission, separate organisations have been established to manage the waste. The operations are financed by the owners of the nuclear power plants through a mandatory production levy paid into a fund under independent management.

3. Prerequisites for nuclear power in Norway

The introduction of nuclear power involves a long-term commitment and the establishment of a comprehensive and complex institutional and regulatory infrastructure. Based on the experiences of countries that have introduced nuclear power, the International Atomic Energy Agency (IAEA) recommends that new nuclear energy countries (newcomer countries) develop a strategy for the introduction of nuclear power that follows a systematic, step-by-step process with clear milestones. The process shall ensure that the introduction of nuclear power is sufficiently justified and anchored both politically and among the public, that the country develops the necessary rules and legislation and fulfils international obligations, including ensuring safety throughout the supply chain, and that it develops sufficient competence and capacity, and ensures financing and cost control. The Milestones Approach involves thorough studies, planning and capacity building across a total of 19 such infrastructure issues.

If the Storting decides that Norway should proceed with the introduction of nuclear power, the Commission recommends that the process follow the steps in the IAEA's Milestones Approach. The process is organised into three phases with three milestones. The first decision the Storting must take is whether to initiate a milestones process and how the process should be organised. Such a decision must be prepared. A decision to initiate a milestones process involves allocating resources to develop a solid knowledge base within all infrastructure issues, so that the Storting has a basis for making a binding decision to establish a nuclear power programme. This is Milestone 1. In phase 2, all the foundations and frameworks necessary for the country to grant a licence for a nuclear power plant are further developed. At milestone 2, the Storting decides whether to open the process for specific licence applications. Phase 3 includes all activities leading up to the establishment of the first nuclear power plant, i.e., the authorities' licence processing, supervision and control, and the operators' investment decisions, contract signing and construction. Milestone 3 is reached when the first nuclear power plant is granted permission to start production.

The IAEA recommends that newcomer countries establish a national coordinating body for nuclear power. The infrastructure issues recommended for assessment span various authorities and specialist fields. Such a 'national organisation for the introduction of nuclear power' (abbreviated to NEPIO) is intended to ensure that the decisions taken are based on a comprehensive knowledge base and that a comprehensive framework is developed for, among other things, licensing processes, planning and coordination.

For a newcomer country, the Commission considers that it will take minimum 20 years from the country starts preparations until the first power plant is operational. The IAEA estimates that it takes at least 10 to 15 years from a country making a political decision to initiate the milestones process until the first nuclear power plant is commissioned. This estimate does not include preliminary studies and the democratic processes that must lead up to the Storting's decision to commence Phase 1. Including such a preparatory phase, it is more realistic that it will take at least 20 years from the decision to establish a NEPIO until the first reactor is completed and approved in Norway. If a decision is taken to allow nuclear power that has not been sufficiently investigated and anchored, the risk of setbacks, delays, and cost overruns increases.

The environmental impacts in the supply chains and throughout the life cycle of nuclear power must be assessed. The environmental impact of nuclear power varies throughout its life cycle, from uranium extraction to decommissioning and the disposal of spent fuel. Uranium mining can involve land disturbances and a risk of pollution. Most nuclear energy countries import fuel or materials for fuel production, meaning that the environmental impact of uranium mining takes place outside their own borders. Fuel production results in limited emissions, but generates low-level waste that requires safe management. During normal operation, nuclear power production produces very low greenhouse gas emissions, on a par with wind and hydropower generation, and radioactive emissions to air and water are low. The cooling system can result in significant water consumption and may increase temperatures in affected aquatic ecosystems.

The land footprint, and consequently encroachment on nature and landscape impact per kWh produced is low for nuclear power plants. The construction phase of a nuclear power plant involves greater physical encroachment, particularly in relation to concrete work and transport, than the operational phase. The land requirement for nuclear power, including waste processing and disposal facilities, is small compared with the planning area for onshore and offshore wind power. However, the land is affected in a different way from wind power, and will be unavailable for other purposes for a very long time.

The siting of nuclear power plants must take into account hydrological conditions, ecology, safety, and the risk of natural events throughout the plant's lifetime. The siting of nuclear power plants requires thorough assessments of geology, water resources, grid access and nature and environmental impacts. Among other things, water consumption and thermal discharges must be managed to protect ecosystems. Land use and biodiversity must be integrated into planning, in line with national and international recommendations. Against this background, it is recommended that the authorities establish clear frameworks and take an active role in managing the siting process.

Nuclear power differs from other energy technologies in terms of specific requirements for risk analyses, safety and emergency preparedness. In addition to technical and operational risks, nuclear power involves risks related to radiation protection, national security, emergency preparedness, international obligations, and long-term societal considerations. Three different safety and security regimes must interact and be implemented holistically throughout the entire life cycle of a nuclear power plant. Nuclear safety concerns the protection of staff, the public and the external environment by preventing accidents and minimising the consequences of accidents. Nuclear security involves preventing and protecting against malicious acts, whilst safeguards on nuclear material, nuclear facilities and nuclear technology aim to prevent the proliferation of nuclear weapons material and technology.

The establishment of nuclear power in Norway changes the national risk landscape. International agreements on the non-proliferation of nuclear weapons (NPT) and the IAEA's safeguards regime oblige operators and authorities to implement strict control procedures to ensure the integrity of nuclear material and that nuclear technology does not fall into the wrong hands. Risks associated with any nuclear power plants and the transport and storage of radioactive material must be incorporated into the planning framework. An assessment of the probability and consequences of undesirable events must be included in the national reference scenarios for nuclear preparedness, as well as in regional and municipal risk and vulnerability analyses. Security risk analyses for deliberate, malicious acts must also be included.

It is a national responsibility to ensure the safe and secure management of nuclear power within the country in accordance with international obligations. The current Norwegian regulatory, safety and emergency preparedness regime is adapted to current radiation use. Currently, the authorities' nuclear preparedness organisation comprises participants from ministries, directorates and county governors. In addition, the municipalities and the emergency services, such as fire and rescue, health and police, play key roles in the management of nuclear incidents. Any introduction of nuclear power into the Norwegian energy mix requires that capacity and competence be strengthened among all actors with roles related to nuclear preparedness.

Nuclear power plants must be constructed in accordance with three key safety principles. The three main principles are control of the chain reaction, adequate cooling in all operational and accident scenarios, and containment of radioactive substances. Nuclear power plants must therefore be built and operated with multiple independent barriers and safety and emergency preparedness systems in accordance with the 'defence in depth' concept. The owner and operating companies bear primary responsibility for safety, security, safeguards and emergency preparedness at the nuclear power plant, and at other nuclear facilities such as waste storage facilities and disposal facilities. The operator is responsible for carrying out risk and safety analyses and establishing preparedness and emergency procedures in accordance with national and international regulations.

Under current regulations, nuclear power plants are designated as critical national objects under the Security Act. To ensure the security of a nuclear power plant, measures are required to prevent terrorism, sabotage, theft of nuclear material and cyber attacks. Security must be ensured through security management, physical protection, personnel security and digital security. Personnel security includes, among other things, security clearance and authorisation of personnel, which can make it challenging to recruit staff from abroad for certain positions. In some countries, armed security guards are used at nuclear power plants.

Norway has long experience with nuclear technology based on the research reactors in Halden and Kjeller. The research reactors were in operation for several decades and have provided a basis for research in fields such as fuel technology, materials research and reactor safety. All Norwegian research reactors are now closed, and decommissioning work is underway under the auspices of Norwegian Nuclear Decommissioning (NND).

Norway has no experience with industrial nuclear power production. This means that we lack experience in the construction and operation of nuclear power plants, regulatory capacity and a supply chain. In order to deploy the technology on a larger scale, extensive competence building will be required across sectors, including operating companies, regulatory bodies, emergency preparedness agencies, planning authorities and educational institutions. There is therefore a need for an extensive development of both competence and capacity if Norway is to become a nuclear energy country.

If Norway is to introduce nuclear power, we must develop competence in a range of specialist fields. Among other things, there will be a need to develop Norwegian competence in areas such as atomic physics, nuclear power technology, project management, legal regulation, radiation protection, cyber security and crisis management. Norwegian educational institutions have research groups specialising in nuclear physics and radiation protection, but the current capacity is insufficient for a potential commitment to nuclear power production. This will require significant investments in higher education and technical colleges to ensure the necessary specialised workforce. International experience shows that it takes many years to build sufficient competence.

Norway should develop competence and capacity step by step and ensure that training and staffing are carried out in line with international standards. In the event of a political decision to introduce nuclear power, a national HR strategy must be drawn up to identify competence needs and ensure recruitment, training and knowledge transfer across sectors. Relevant educational pathways and training programmes must be established, and the initiative must have long-term funding and institutional underpinning. Increased participation in international networks and research collaboration is crucial to keeping Norwegian competence up to date and ensuring that we keep pace with international developments. A shortage of nuclear power expertise is expected in the EU, and it will be challenging to meet the demand in Norway through extensive recruitment from abroad.

4. Regulation and organisation of authorities

There is extensive international regulation governing nuclear power, which also applies to Norway. This stems partly from the need to prevent the proliferation of nuclear weapons, and partly from the fact that accidents can have cross-border consequences. Norway is a member of or a contracting party to the organisations and international instruments relevant to the regulation of nuclear power, with the exception of Euratom (the European Atomic Energy Community). Norway is therefore unable to benefit from the advantages and rights conferred by Euratom membership. Norway may seek closer ties with Euratom through a bilateral agreement or through an extension of the EEA Agreement. Developing nuclear power without being affiliated with Euratom means that Norway must, to a greater extent, build competence and develop regulations on its own.

Experiences from other countries can provide useful inspiration for regulations and the organisation of authorities relating to nuclear power. The Commission has examined Poland, Finland, Sweden, the UK, Canada and France, with Poland being a newcomer country, whilst the others are considering or have decided to develop new nuclear power. All countries have initiated a review of frameworks, regulations and the organisation of authorities, and several have introduced a NEPIO-like structure to coordinate the processes. All countries emphasise the development of appropriate licensing processes. In general, responsibility for the establishment of nuclear power and radiation safety, respectively, is assigned to different ministries to avoid conflicts of interest. The state plays a strong direct and/or indirect role in the financing of new nuclear power through various instruments such as contracts for difference, loans/guarantees, or ownership. All countries have established fund arrangements for the financing of the final treatment and disposal of nuclear waste. Design choices (large-scale and/or SMR development) are an issue in all countries.

Current Norwegian regulations for nuclear power are set out in various laws and are not adapted to commercial nuclear power production. The Nuclear Energy Act provides a legal framework, but the regulations do not contain a comprehensive structure for licensing processes for nuclear power plants. The licence processing for nuclear power plants is a matter of energy policy. The Energy Act and the Nuclear Energy Act operate in parallel, which can lead to duplication of work and an unclear allocation of responsibilities.

Under current regulations, the governmental responsibility for licence processing for nuclear power plants is fragmented. The allocation of responsibilities is based on the sector principle, which does not provide a clear allocation of responsibilities in the licensing process. Responsibility in the licensing process covers tasks that affect a number of authorities and subject areas, such as responsibility for power production and security of supply, pollution, radiation protection, safety and security, and national security interests.

Designing the best possible regulatory framework for nuclear power in Norway is a question of the methodology for regulatory development, the structure, and the content of the overall set of regulations. The IAEA's Milestones Approach recommends a procedure for developing a legal and regulatory framework that takes place gradually through three phases, with clear milestones. A key issue regarding the structure of the regulatory framework, and an important premise for its development, is the extent to which legislation on nuclear power should primarily be consolidated into a single act, or whether we should retain the current legislative structure. The assessment should also cover the purpose provision, overall state management, licencing and application processes, the coordination of arrangements for safety, supervision and emergency preparedness, as well as the waste management system. The need for regulation tailored to all types and sizes of nuclear power must be assessed when the regulations are revised.

The regulatory framework must take a number of considerations into account. The regulations must cover the protection of people and the environment, the protection of the nuclear power plant and other nuclear facilities, the protection of society and security of supply. The regulations must also set requirements for the competence of the authorities and those responsible for constructing and operating a nuclear power plant, ensure that the establishment of nuclear power plants is subject to authorisation, and ensure that the consequences are adequately assessed in advance.

With the introduction of nuclear power in Norway, the assignment of governmental responsibility at the national level must be clear, and emphasis must be placed on mechanisms that ensure coordination. Models for coordination between laws and authorities must therefore be further developed. The organisation of authorities must cover various nuclear facilities such as nuclear power plants, fuel cycle facilities, waste management facilities and disposal facilities.

With the introduction of nuclear power in Norway, there is also the question of how the relationship between central government, regional government and local government should be organised. Among other things, there is a political question as to whether the current system for wind power, which requires a municipal land-use plan before a state licence is granted, is also appropriate for future nuclear power.

A nuclear power programme requires an independent radiation safety authority. International regulations stipulate requirements for independence between the radiation safety authority and other authorities. Independence means that higher-level administrative bodies, including the Government, do not, in individual cases, have the power to issue instructions to the subordinate independent administrative body for such safety, and that the body has sufficient technical and financial resources.

Regulation of the organisation of authorities should include an assessment of models for the financing of regulatory tasks. It may be considered to what extent the processing of applications and licences for nuclear power plants and any other licences can be fee-financed. It may also be considered whether fee financing should cover any regulatory work related to identifying suitable sites for nuclear power plants or other nuclear facilities. In addition, the assessment should cover the financing of the emergency services' preparedness work, as well as that of host municipalities and, where applicable, neighbouring municipalities.

The IAEA's Milestones Approach does not provide recommendations on how a country should make the decision to include nuclear power in their energy mix and initiate a milestones process. A process leading up to a political decision must be transparent and predictable and comply with regulations on public involvement.

An application to establish a nuclear power plant will encompass a range of political considerations and involve various authorities. If it is decided that Norway should include nuclear power in its energy mix, the Nuclear Energy Act states that the Storting should consider each individual nuclear power project.

5. Nuclear power in the Norwegian power system

There is broad political consensus that the demand for power in Norway will increase in the future. This increase in consumption is linked to the climate challenge, which requires electrification to reduce fossil fuel use and cut CO2 emissions, and to the development of new industries, some of which are highly power-intensive. However, the extent of this growth in demand is highly uncertain and also depends on price trends and energy efficiency improvements.

Norway has a power system dominated by hydropower with reservoirs, and it has resources to develop more renewable energy. Today, around 90 per cent of Norway's power production comes from hydropower. Unlike other countries, Norway does not need to replace large parts of its existing generation capacity. There are several notifications and applications for the development of new hydropower, onshore wind power and solar power in the coming years, and energy use in households and the wider business sector is becoming increasingly efficient. As nuclear power cannot be established in Norway until the mid-2040s at the earliest, it will contribute little to meeting the 2050 climate targets. Nuclear power must therefore primarily be seen as a potential solution for meeting long-term demand.

Offshore wind offers the greatest potential for new power generation in the long term. If we see strong growth in demand towards 2050 and limited development of onshore wind power, it is offshore wind that offers the greatest potential for new generation in Norway. Offshore wind development in Norway is at an early stage, with the first fixed-bottom offshore wind project at Sørlige Nordsjø II scheduled to come on stream by 2032. This project has received state aid, and the Storting has set aside funding for support for the first floating offshore wind projects. Future cost trends for offshore wind are uncertain.

Nuclear power has both advantages and disadvantages compared to the alternatives. Nuclear power has good system characteristics, is operationally reliable, dependable and has high availability. Nuclear power requires little land area per kWh, has limited encroachment on nature compared to the alternatives, and can, to a greater extent, be located where it is most beneficial for the power system. It can therefore fit well into the Norwegian power system. As the Norwegian power system is dominated by flexible hydropower, wind and solar power also fit well into our system. On the other hand, nuclear power requires a specific safety and emergency preparedness regime relating to the use, transport, and handling of radioactive material. Established technology is based on uranium, which must be imported. It takes longer to develop a nuclear power plant than to build out renewable production. Currently, cost estimates for new nuclear power and floating offshore wind are of the same order of magnitude, but with considerable uncertainty. With learning effects resulting from technological development and increased deployment, costs may be reduced in the future.

The introduction of nuclear power means that the state assumes responsibility and obligations even if the development is carried out by commercial operators and without state support. A state that permits nuclear power retains a financial risk even if the owner and operators take out insurance against accidents or other undesirable events, and even if the developer sets aside funds on an ongoing basis for decommissioning and a disposal facility. This is because a private operator may go bankrupt, which would necessarily limit its financial liability.

The Norwegian power system can be adapted to the development of both renewable power and nuclear power. The composition of generation capacity affects both the operation of the power system and the planning of the transmission grid. In Norway, Statnett is responsible for both. Statnett plans the grid to ensure it is robust in the face of various future scenarios and has several mechanisms and tools to operate the grid with a high level of security of supply. Nuclear power has favourable system characteristics compared to wind power, but these are not decisive for the operation of the power system. Hydropower's regulating capacity means that Norway has greater freedom than many other countries when considering the introduction of nuclear power. Statnett's current plans for a robust power system over the coming decades do not assume the presence of nuclear power plants in Norway, and Statnett's analyses show that a decision on nuclear power would not significantly affect grid planning. However, this assumes that nuclear power is located where the grid is already strong and the power balance is weak to begin with.

A decision to consider a nuclear power programme may affect market developments and investments in other power plants. Norway has a market-based power system, in which the state sets the framework for investments in power generation, and investment decisions are taken by private operators on commercial terms. The prospect of realising a Norwegian nuclear power programme with production starting in the mid 2040's may crowd out other power plant investments that can be realised more quickly. This will lead to a weaker power balance in the short and medium term before nuclear power comes on stream, and may result in a stronger power balance and increased exports once nuclear power starts generation. A higher probability that Norway will adopt a nuclear power programme may similarly lead to other power plant investments being put on hold. The extent of the impact will depend, among other things, on demand trends and developments in the markets surrounding Norway.

Market prices are the most important factor for the profitability of nuclear power. Nuclear power derives almost all its revenue from the sale of power on the market. Expectations regarding future market prices also underpin the prices in long-term contracts. There is considerable uncertainty regarding future power prices. Nuclear power plants prefer to generate continuously around the clock and schedule maintenance and fuel replacement for periods when prices are low. Therefore, they achieve a slightly higher price than the average market price. It can also be profitable to reduce production during periods of very low market prices. In addition, nuclear power can generate revenue from the sale of system services and guarantees of origin. However, at current prices and volumes, this makes little difference to the overall accounts. Capacity payments are unlikely to be relevant in Norway, and heat from nuclear power plants in Norway will probably be of little value.

If nuclear power is to become profitable in Norway in the coming decades, costs must be reduced significantly. Because planning, financing and governmental processes take a long time, the relevant costs are those of nuclear power plants with construction starting 10 to 15 years from now. For the investment to be profitable, the net present value of revenues and costs must also be positive. Power prices and the capital cost are therefore crucial. Given the current range of cost estimates for nuclear power, large-scale nuclear power plants require power prices of between just over 130 and just under 220 øre/kWh to be profitable. In other words, significant cost reductions are necessary if nuclear power is to become profitable in Norway. An SMR-based development can generate revenue earlier than one based on large-scale reactors. Even with the lowest cost estimate, SMRs must still achieve a power price of just over 110 øre/kWh to be profitable. Nuclear power has minor positive and negative socio-economic external effects, which combined do not provide a basis for making the socio-economic profitability significantly higher than the commercial profitability.

Profitability assessments depend on the discount rate used. The discount rate (or the required rate of return) shall reflect the alternative return on invested capital, how future amounts are valued compared with current income and costs (time preference), as well as the financial risk associated with the project. The Commission has not carried out its own assessment of which discount rate is appropriate to use but has based its calculation examples on a discount rate of 5 per cent, in line with the interest rate used in the valuation of listed power companies in Europe. Experience shows that a number of Norwegian power companies have a somewhat higher required rate of return. Although a lower discount rate – down to 2 per cent for effects far into the future – could be argued for public investments, the Ministry of Finance requires socio-economic analyses of activities in direct competition with private operators to use a discount rate corresponding to that faced by private companies.

The Commission finds no socio-economic arguments for state aid for nuclear power in Norway. State aid can, in principle, be justified on the grounds of market failure, incomplete markets, significant positive externalities, and industrial and security policy objectives. The Nordic power market is characterised by free competition, freedom of establishment, and framework conditions that address externalities through licence conditions, requirements and CO_2 pricing. Nuclear power has positive system characteristics and stable production. They are compensated for both in the markets. It is therefore not an externality. The industry is willing to enter into long-term power purchase agreements, and financing opportunities for power plants are generally good. Norway has no experience with commercial nuclear power and fundamentally no particular advantages for building up a nuclear power industry. Norway is not dependent on energy imports, and the power supply is spread across the country. On the other hand, nuclear power involves concentrated production in a small area and the import of energy in the form of low-enriched uranium for nuclear power production, which could weaken energy security.

The risk does not disappear even if the state takes a role in a project. It is merely transferred to the state. The fact that financing is costly or difficult to obtain may be a sign that the underlying economic risk is high or that profitability is low. This is not in itself an argument for state involvement. The state must also weigh the risk of investing against the risk of not investing in nuclear power.

State aid for nuclear power in order to reduce investment risks for operators must be assessed on the basis of its purpose and weighed against alternative policy instruments. Regardless of the purpose, it should be assessed whether state aid is the most appropriate government instrument, or whether other forms of state involvement, such as regulatory measures, would be better suited to achieving the same objective.

6. Ethical and societal trade-offs

The development of nuclear power plants in Norway may have significant economic ripple effects. The planning, construction, operation and decommissioning of nuclear power plants are resource-intensive activities that will generate significant demand for labour, capital and inputs. The OECD-NEA estimates total direct employment of around 50,000 person-years over the lifetime of a 1 GW nuclear power plant. In addition, there is demand for labour in other parts of the value chain.

From a national perspective, the ripple effects are primarily a redistribution of resources. The construction and operation of a nuclear power plant increase employment in the host municipality. From a national economic perspective, however, high resource use is not necessarily positive. Increased resource use in one municipality draws resources from others, and increased resource use in one sector draws resources from others. The key question is whether resources are put to better use in the nuclear power industry than in other industries. A reallocation of resources to nuclear power does not automatically increase value creation in the economy as a whole. On the contrary, politically directed resource use, e.g. through subsidies, can divert resources such as labour and capital away from other activities that generate greater value creation.

Previous analyses indicate that a significant proportion of the demand for labour, capital, and intermediate goods can be met by domestic labour and production. However, the transferability of foreign impact analyses to Norwegian conditions is uncertain, as Norway has no experience with nuclear power.

Resources freed up from the petroleum industry over the coming decades can be utilised in other industries. In principle, resources freed up from the petroleum industry could also be utilised in a potential nuclear power industry. However, the fact that such a transfer is possible is not in itself an argument for developing nuclear power. Freed-up resources should, in the same way as other resources, be used where they generate the highest value creation for the economy as a whole.

The risks associated with nuclear power are considered low within established safety frameworks. Nuclear power is characterised by a low probability of serious accidents, whilst the consequences can be severe. For events with a low or unknown probability, risk assessments are uncertain because the knowledge base is incomplete. This may, for example, be due to limited data, model simplifications, and an incomplete understanding of physical processes and human and organisational behaviour under extreme conditions. In such cases, therefore, the expected value cannot be the key assessment criterion; rather, it is the management of low-probability events with very severe consequences. Even an unlikely event can occur.

In principle, knowledge uncertainty can be reduced through increased knowledge and experience, but it can never be fully eliminated. Where uncertainty can be described in terms of known frequency or probability, the use of probability calculations, statistical methods and simulation is legitimate. Knowledge uncertainty, on the other hand, raises questions regarding the validity of models, robustness, conservatism and the need for explicit decision-making and assessment principles. Models and data cannot cover all possible combinations of events and all possible consequences.

Some events or chains of events are also not suited to probability-based risk assessments, such as deliberate, malicious acts intended to cause harm.

A comprehensive understanding of risk is necessary for robust decisions on nuclear power in Norway. Risk must be assessed both from a life cycle perspective and in the context of broader societal considerations, including climate risk, technological development, geopolitical conditions and long-term waste management. Risk assessments provide important insights into probabilities and consequences, but cannot alone determine the question of nuclear power.

At the intersection of what risk analyses can and cannot illuminate, ethical considerations become important. Nuclear power touches on fundamental questions of values relating to justice, responsibility and risk. When uncertainty is significant, the consequences potentially far-reaching and long-lasting, and the knowledge base limited, decisions become normative. Technical risk analyses say little about what is acceptable, who should bear the risk, or which considerations should carry the most weight when values conflict. Traditional cost-benefit analyses do not capture values such as loss of nature, intergenerational equity, and risks that are difficult to measure or compare on a common scale. Decisions on nuclear power must therefore be assessed in the light of ethical principles.

Responsibility towards future generations and the balancing of different values are key ethical issues associated with nuclear power. The storage and disposal of spent fuel, and the very long time horizon over which the technology's consequences extend, distinguish nuclear power from other energy sources. This raises dilemmas related to irreversibility and the 'polluter pays' principle, which should be assessed on the basis of ethical principles. Ethical assessments of nuclear power involve weighing different values that are often in conflict with one another. A key question is how nuclear power should be assessed against alternative energy sources in light of the energy trilemma: energy security, sustainability and equitable distribution. Nuclear power necessitates choices between considerations such as land encroachment, the climate targets, the risk of accidents, geopolitical dependence, the use of scarce resources, and the burdens imposed on future generations. Ethics cannot provide unambiguous answers, but it clarifies which values are at stake and what justifications must underpin a political decision.

Societal acceptance is a fundamental prerequisite for the introduction of nuclear power in Norway. The development of nuclear power will not be possible without stable support from the public, from political actors, and from the local communities affected. Societal acceptance is not about avoiding opposition, but about ensuring the legitimacy, trust and perceived fairness of decision-making processes, and the distribution of consequences. Experience internationally and from Norway's energy and industrial history shows that a lack of support for projects can lead to major conflicts, costly delays and complete standstills.

Acceptance is shaped over time and depends on open processes, genuine involvement and clear frameworks. Opinion polls provide snapshots of attitudes, but are not suitable for explaining acceptance. Acceptance is conditional and context-dependent, and is influenced by factors such as nature conflicts, power prices, safety, geopolitics and trust in the authorities. International experience from the construction of nuclear power plants and disposal facilities shows that local decision-making powers, open information, visible benefits and robust processes over time are crucial for building and maintaining trust.

Any nuclear power initiative requires early, clear and continuous buy-in throughout the entire process. Acceptance must be built before decisions are taken, by making clear the purpose, risks, trade-offs and alternatives. Processes must be transparent and provide the public, and the municipalities affected, with a basis for genuine influence at all stages, through clear frameworks, open information and the possibility of compensation for the additional burden. Throughout the entire period, from study and siting to operation, decommissioning and disposal, work on dialogue, information, emergency preparedness and openness regarding advantages and disadvantages will be necessary to maintain legitimacy. Achieving and securing acceptance is not a one-off task.

7. Recommendations

The Commission considers that nuclear power can be established, operated and decommissioned with low risk to health and the environment in Norway. The prerequisite is that the development is planned systematically based on international standards for safety, security and safeguards of nuclear material and technology. Risk analyses based on probability calculations must be supplemented by normative and institutional frameworks that include precautionary principles, conservative design and defence in depth. National and local authorities, as well as stakeholders involved, must possess a high level of expertise and sufficient resources, and the safety of each individual site must be assessed separately.

It will take at least 20 years to establish nuclear power production in Norway. For a newcomer country, as Norway would be, comprehensively developing the necessary regulations, clarifying the allocation of responsibilities between authorities and establishing the necessary infrastructure is an extensive and long-term process.

It is a major and important decision whether Norway should become a nuclear energy country. A political decision on the introduction of nuclear power in Norway must be based on assessments of and trade-offs between a range of considerations and a firmly anchored democratic process. Economic, technological and ethical aspects must be included in the assessment, not least in light of the long-term commitment that the establishment of nuclear power involves.

If Norway is to commit to nuclear power, this will require extensive governmental processes. As a basis for the necessary democratic processes, the authorities must clarify a number of requirements and provisions. Relevant provisions include overall governance of and requirements for siting, including grid considerations; which licensing requirements are to be set and how; which procedural steps the application process should include; and how the necessary coordination between authorities is to be ensured. Responsibilities and requirements relating to the security of the facilities, as well as decommissioning, waste management and disposal facilities, must be established. The relationship with Euratom must be clarified, and the risk landscape and procedures for early warning and consultation with neighbouring countries must be updated. To ensure sufficient competence and capacity within the public sector and industry, Norway must expand and develop research and education across a range of disciplines.

Nuclear power in Norway is not economically profitable given current cost projections and market prices. Due to the high fixed costs associated with establishing a disposal facility, as well as the extensive governmental apparatus that must be built up, it would become disproportionately expensive to develop ‘a small amount’ of nuclear power in a country. In Sweden and Finland, stakeholders are talking about 4 to 5 GW, equivalent to 30 to 35 TWh, as a realistic scale. From today’s perspective, nuclear power does not appear to be commercially profitable. Looking ahead to 2050, Norway has good alternatives that are either established or under development, and as things stand, the Commission finds no specific socio-economic justifications for state aid for nuclear power, such as security of supply or the climate targets. Nuclear power can make only a minor contribution to meeting the 2050 climate targets and must primarily be seen as a solution to meet increased energy demand after 2050. A political decision to introduce nuclear power now could delay investments in other generation capacity, which would be able to come online sooner. Due to its hydropower, the Norwegian power system is not dependent on the system characteristics of nuclear power.

The Commission therefore recommends that a comprehensive process for the introduction of nuclear power in Norway should not be initiated at this stage. The prospect of inadequate profitability and the extensive governmental apparatus that would need to be built up are key reasons for this. Ultimately, it is investors who will assess whether nuclear power should be realised, and they will weigh the profitability of nuclear power against other investments. Extensive and resource-intensive public processes may therefore prove fruitless or require substantial state subsidies in addition.

Uncertainty regarding future developments suggests that nuclear power may become an option for Norway at a later date. Offshore wind may prove to be more expensive than expected, and the development of onshore renewable power production may be weaker. Demand growth may be higher and imports from abroad more expensive. Technological development and learning effects may make nuclear power cheaper. New nuclear power currently being planned is based on existing technology, where ambitions for industrialised, module-based design have not yet been realised. The development of new technologies is a long way off. Norway has no experience of commercial nuclear power production, and it will in any case take a long time to develop the necessary competence.

The Commission recommends that a national competence project be established to enable a faster introduction of nuclear power should this become relevant in the future. The Commission has argued that given the current situation, it will take a long time to initiate and carry out the processes required to introduce nuclear power in Norway. In the future, the cost situation and the trade-offs between costs, the environment, land use, safety and other values may change. A national competence project spanning relevant ministries, agencies and sectors could lay the groundwork for and shorten any future process.

A national competence project must be given a clear mandate. The Commission points out that the mandate should include regular updates on the status of technological, commercial and economic developments in nuclear power, and that relevant agencies could be tasked with including nuclear power as a potential technology in their long-term market analyses. The project should assess how the IAEA's Milestones Approach can be adapted to Norwegian conditions, and identify clarifications and preparations that can be made in advance. One relevant area is regulations and division of responsibilities between different national authorities. Another relevant task could be to prepare a national framework for the siting of nuclear power plants and disposal facilities, and to assess the potential responsibilities of host municipalities and how affected neighbouring municipalities should be involved.

Norway should invest in building up critical competence and research environments. Nuclear power requires specialised competence in a range of disciplines, and establishing nuclear power requires building up extensive competence and capacity. Adequate educational programmes can be established relatively quickly, but this depends on the availability of up-to-date research competence in the relevant fields. The Commission proposes that a limited but targeted academic environment in nuclear power technology be established at Norwegian universities and that better conditions be created for participation in international research programmes. A national competence project should define a targeted competence enhancement in more detail. Finally, the project should investigate the possibilities for more extensive cooperation with Sweden and Finland on regulatory development, competence building, research infrastructure and knowledge exchange in various areas. For any future decision on nuclear power to be perceived as legitimate, fair and confidence-inspiring, trust in the processes must be established. Therefore, important ethical issues should also be addressed in a competence project.