# The green shift – extracting synergies from the oil and gas sector when establishing nuclear in Norway

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**Abstract**

Today, the oil and gas sector is by far the main driver in the Norwegian economy but also a main contributor to Norway’s CO2 emissions. To achieve the national goal of (close to) net zero emissions by 2050, it is of paramount importance to the Norwegian economy to identify and extract synergies from the oil and gas sector in the transition to competitive clean energy systems of the future. In the present paper we emphasize that investments in SMR technology can be an alternative to small- to medium sized oil and gas fields in Norway. SMRs may also play a crucial role in decarbonization and electrification of the oil and gas industry during the transition phase, while simultaneously enabling the use of process heat for carbon capture and storage, and the production of hydrogen and synthetic fuels. Further, similarities between the sectors may facilitate transfer of competence and work-force as well as supply chains between the industries while creating new business opportunities for the Norwegian oil and gas sector.

## Introduction to Norwegian oil and gas

In the 1960, Norway’s venture into the oil and gas industry began, with the first significant discovery of oil in December 1969 at the Ekofisk field, south of Stavanger, in the North Sea by the Phillips Petroleum Company. The finding marked the beginning of the transition of Norway into a major supplier of oil and gas (O&G) resources.

 In the initial phases of the exploration for Norwegian O&G resources, in the 60s to 70s, the Norwegian government took on a strategic role, enabling the regulatory frameworks, encouraged the establishment of national supply chains and prepared for state participation, while the exploration activities themselves were provided by already experienced global companies such as Esso, Phillips Petroleum and Shell. When large oil companies challenged the notion that Norwegian supply chains had the necessary proficiency to partake in the O&G industry, Norwegian officials referenced the Norwegians’ early entrance to the field of nuclear science, building and operating its first nuclear reactor already in 1951, providing credence to the Norwegian industrial aptitude. Significant localization of supply chains and ownership of the natural resources was eventually assured.

 In 1972, Statoil (now Equinor) was formed by the Norwegian government to secure state control and significant participation in the O&G industry. Production and revenue rapidly expanded in the 80s and 90s after discovering additional significant fields including Statfjord, Oseberg and Gullfaks. In 2001, a new era of global expansion and increased efficiency begun for Statoil as a part of a partial privatization of the company. Equinor (Statoil’s new name since 2018), is today the largest operator on the Norwegian continental shelf (NCS), accompanied by international companies such as Shell, Total, BP, and ExxonMobil, as well as Norwegian companies such as Aker BP, OKEA ASA and Vår Energi.

 Revenues from the O&G industry has played an increasingly important role in the Norwegian economy. In 2023, 62 %, approximately NOK 1200 billion, of the total export values of Norwegian goods were accounted for by the O&G industry, demonstrating the significance of the Norway’s natural resources on the NCS [1]. Through the Sovereign Welfare Fund, established by law in 1990, much of the monetary values of these natural resources are essentially owned by the Norwegian public, ensuring large yearly additions to the Norwegian state budget, funding services and infrastructure such as hospitals, education, roads, research etc.

## Introduction to Norwegian nuclear history and infrastructure

Despite not yet having established nuclear power, Norway has a long history within the nuclear domain and has already implemented and matured the infrastructure needed to implement nuclear power. In 1951, the first Norwegian nuclear reactor, JEEP 1, was put into operation, three years after the decision was made to pursue nuclear technology in a peaceful manner. As such, Norway was one of the first countries in the world to deploy nuclear reactors. Throughout the 50s and 60s, three more research reactors, the HBWR, NORA, and JEEP II, were constructed, the latter of which was operated until 2019. All were owned and operated by the Institute for Energy Technology (IFE, then IFA, the Institute for Atomic Energy), providing valuable research to the global nuclear domain and even the Norwegian O&G industry where the issues of three-phase flow was solved, culminating in the OLGA-software, significantly contributing to Norwegian O&G production and revenues.

 In the 70s, it was anticipated that hydropower resources, which made, and still makes up, the vast majority of Norwegian electricity production, would eventually be depleted and so nuclear power was briefly pursued. New legislation was established, the Atomic Energy Act no. 28 of May 1972, and the Norwegian government commissioned a national assessment (Official Norwegian Report; NOU) of nuclear power’s potential role in the Norwegian electricity mix, and the Norwegian Directorate for Waterways and Energy (NVE) identified a multitude of suitable sites. [2, 3] However, despite the NOU concluding positively to establishing nuclear power in Norway, the pursuit towards nuclear power was halted and political interest dissipated. Hydropower resources were better utilized, and much of the political and industrial efforts were rather focused on building the O&G industry. Notably, this shift also coincided with a lack of public support for nuclear development, stemming from concerns about safety and seemingly also from the “top-down” implementation approach used at the time with government agencies planning nuclear sites without much prior local involvement and acceptance.

 The pursuit of nuclear power in the 70s did, however, largely prepare Norway to embark on such endeavors in the future. Norway has also established an independent nuclear regulator, the Norwegian Radiation and Nuclear Safety Authority (DSA), and Norway is party to several international conventions related to nuclear safety, spent fuel management, waste management, and early notification. Several educational programs directed towards the nuclear sphere has been established, and the Atomic Energy Act is supported by a number of acts, regulations and guidelines, which combined sets out a clear path to safely and securely plan, license, construct and operate nuclear power plants, as well as appointing the various responsible authorities for overseeing these activities.

Altogether, the existing, well established nuclear infrastructure and long history in the field of nuclear technology, along with high availability of private and public capital, much thanks to the O&G industry, Norway is well situated to embark on nuclear power.

## The renewed interest for Norwegian nuclear power

As is the case in many other countries, Norway anticipates a significant increase in clean energy demand due to the need to cut greenhouse gas (GHG) emissions, an expected population growth, and expanding existing- and developing new industries. By 2050, several hundred new TWh’s of clean energy production is stipulated. In recent years, the possibility of establishing nuclear power has been discussed to an increasing extent in the national discourse, where both challenges and advantages have been highlighted. As the topic has increasingly been discussed by NGOs, politicians and other public figures, as well as industrial entities, the popularity has also grown significantly from being the most unpopular energy source in 2017 to now being the most popular energy source, even more popular than hydropower, and far exceeding the popularity of wind and solar power, according to recent polls [4]. The Russian aggression towards Ukraine and associated increasing power prices, also highlighted the need for security of power supply, possibly increasing the positive public perception of nuclear power additionally.

 After decades of marginal top-level political interest, almost all parties in the Norwegian Parliament, have implemented positive policies or provided Parliamentary proposals in favor of nuclear power in Norway, and the Norwegian government decided in May 2024 to conduct an NOU, an official assessment, to consider the potential implementation of nuclear power in Norway.

 Many municipalities have also implemented positive decisions to be a potential future host of nuclear power plants, and over 40 municipalities and counties have recently formed the organization “Norwegian Nuclear Municipalities” to increase awareness and knowledge about the energy source and lobby for their mutual interest towards the government. Other organizations, such as the Norwegian Nuclear Association and the NGO “Climate Friends for Nuclear” has also been established partly or fully in response to the need for nuclear power to address climate concerns and foster sustainable growth.

 As for interest from the private sphere, in 2022, the company *Norsk Kjernekraft* (NK, English: Norwegian Nuclear Power) was established by several high-net-worth individuals with backgrounds in a multitude of industries, among these the O&G industry, to implement SMR-NPPs into the Norwegian energy mix from the 2030s and onwards. The company aims to be operator of these SMRs, utilizing Nth of a kind (NOAK) technology, and sharing ownership with existing utilities, new and existing energy-intensive industries, as well as Norwegian host municipalities, establishing such structures through several Special Purpose Vehicles (SPVs) for the most promising sites. The company adopts the IAEA Milestones Approach, conducting several studies and assessments (see for instance feasibility study of implementing nuclear power program [5]), embarking on the Norwegian permitting process and emphasize industrial and public engagement, communicating both challenges and advantages in a “bottom-up” manner rather than “top-down” approach used in the 70s, as described earlier. Additionally, learnings from the strategy used in the 60s and 70s when Norway embarked on its O&G venture are employed, making sure the Norwegian nuclear program attracts, and is assisted by, already existing global expertise in the field of nuclear power.

## TRANSITIONING THE O&G INDUSTRY

The Norwegian O&G industry produced an energy equivalent of 2510 TWh in 2022, were most were for export, 2335 TWh [6]. This represents a significant volume, 25 % of EUs gas consumption is from Norway, and more than 40 % of Germany’s [7].

The production of O&G generated 12 million metric tons (MT) of CO2 equivalents in 2023, approximately one quarter of the total Norwegian emissions, and is the single largest emitting industry of Norway. Most of these emissions are associated with energy production for O&G installations offshore, where gas turbines accounted for 8.35 million MT and usage of diesel for 1.13 million MT. Gas turbines on onshore facilities produced 1.39 million MT and the rest is associated with flaring, venting and leakages, and loading of oil, in descending order [8].

To meet the Norwegian climate ambitions, to adhere to the industry’s social responsibility, and to avoid tax levies of approximately 175 € per MT CO2 (the level set by the Norwegian government for 2030) or more, these emissions need to be cut dramatically, mainly through electrification by low emitting sources. Although Norwegian authorities have required low carbon electricity for offshore O&G installations in connection with establishing new oil fields or significant renovations of existing fields since 1969, by 2023, only 13 % (9 out of 68 TWh) of the electricity consumption of the O&G sector had been electrified by clean sources [9].

### Current strategies for electrification

Existing strategies for electrification of the remainder of the O&G sector can roughly be separated into two main paths: electrification via sea cable to the onshore grid or through installing and connecting offshore wind power. The main issue with the former option is that the onshore grid is already strained and both onshore wind power and expanded hydro power is either unpopular or the natural resources are depleted. Furthermore, even if a license to connect may be obtained, these licenses will include provisions for disconnection to preserve onshore grid stability when necessary, leading to low reliability.

Issues with the latter strategy of offshore wind is generally high costs, wake effects, “cannibalization” effects, severe volatility (power production is roughly proportional to the wind speed cubed), and the need for back-up power production by offshore gas turbines. In practice, the “back-up” gas turbines need to be online almost continuously, and operated sub-optimally, to account for wind variability. According to planning projections, as well as *Applied Energy* by Jan Emblemsvåg [10], 80-85 % of the GHG emissions will remain after the offshore wind turbines are connected, leading to approximately 400 g CO2/kWh emissions for the system (offshore wind and gas turbines for back-up). Yet, this option is currently favored over attempting to connect to the onshore grid, partly due to low availability of new grid connections, and partly due to political and public sentiment.

Recently, the first of a kind (FOAK) offshore wind-project, Hywind Tampen, was put into operation. This is the world’s largest offshore wind power plant, with an installed capacity of 88 MW, costing almost 1 billion Euros. At such high costs relative to production and low cuts in GHG of O&G production, such projects are challenging to provide the owners with a positive Net Present Value (NPV), and, as such, significantly hindering further electrification projects.

## TRANSITIONING THE O&G INDUSTRY BY SMRS

An alternative strategy is electrification of the offshore O&G installations by use of partly or fully dedicated SMRs. Offshore nuclear power plants may be attractive options and may be feasible in the coming decades. However, so as to not include too many novelties in the electrification strategy, a reasonable option is to site the SMRs conventionally, onshore, and connect to offshore installations via existing or new sea cables. This way, the SMRs may also be used to electrify onshore installations, supporting additional industries like steel manufacturing, mineral processing, fertilizer production, marine food production such as salmon onshore aquaculture, battery factories, datacenters etc. and increasing the redundancy and security of supply of the onshore grid.

 At the shores near offshore O&G installations there are usually many sites available where infrastructure serving the existing O&G installations is already in place, such as ports, service businesses, access roads, human resources, available housing or land for housing etc. Such sites also provide ample access to year-round cold water for efficient cooling of the SMRs, which is easily accessible throughout the Norwegian coastline (Norway has the second longest coastline in the world).

### The investment case

An Overnight Cost of Capital (OCC) of approximately 1-2 billion Euros per SMR producing approximately 300 MW electric is generally anticipated for a NOAK SMR, close to NOAK, or as a unit cost when constructing a fleet of SMRs. This investment level may be comparable to the cost of developing and establishing an oil field with a potential production of fifty to one hundred million barrels of oil per year. However, the actual size of the field, how much oil may technically be extracted, and the selling price of the oil, adds uncertainties and financial risks. Lately, political decisions and increasing carbon taxes are increasing risks associated with such investments further. Compared to SMRs, which will benefit from stable and far greater energy production during its lifetime, political and public good-will, increased competitiveness due to carbon taxes, and low and predictable operational costs, the investment risk is lower, particularly if NOAK SMRs or a fleet of SMRs serving multiple industries are employed.

 Furthermore, there are great potential prospects for asset value increase even after commercial operation date (COD), due to possible plant uprates, increasing energy production via technical modifications, and utilization of heat using techniques not available or applied initially, such as some prospective hydrogen production technologies like solid oxide electrolysis (SOE), carbon capture and storage (CCS) or utilization (CCU), fish farming, or cooling- or freezing techniques. If only 10 % of the excess heat from a light water reactor may be utilized, this may increase the volume of sold energy by 20 %, indicating great potential for such prospects.

For investments in the O&G industry, the Petroleum Taxation Act, Act no. 35 of 13 June 1975, also provides opportunities to de-risk investments, as investments securing production of O&G, such as an SMR securing lower emissions O&G production, will be entitled to tax deductions of approximately 78 % of the investment. This mechanism has already been demonstrated for power production facilities dedicated to electrification of O&G platforms, such as the offshore wind project Hywind Tampen, previously referenced. An OCC of initially 1-2 billion Euros for an SMR, would then in practice only necessitate approximately 200 to 400 million Euros of owner’s investment. This represents significant opportunities, not only for making the Norwegian O&G sector more sustainable, but also to enable a substantially lower financial threshold for implementation of nuclear power in Norway to also enable cutting GHG emissions in subsequent industries.

 Conservative estimates for NPV of such SMR projects, excluding tax benefits enabled by the Petroleum Taxation Act, are in the hundreds of millions of Euros per SMR, indicating more than sufficient margins to pursue the prospect of SMRs for enabling cleaner O&G production on the NCS, as well as reducing emissions, and fostering growth, in other industries.

Due to the long lifetimes of nuclear power plants, potentially spanning many generations, assets initially established to cut emissions for the O&G industry may also serve as new business opportunities for companies in the industry to enable growth even after demand for O&G, or availability of O&G on the NCS, declines.

### Potential sites

As previously discussed, there are plenty of siting opportunities at coastlines near offshore O&G installations. Often present at such sites, and in Norway in general, is stable bedrock, low seismicity, stable climate, and abundant available land.

 Norsk Kjernekraft is the early planning phase for several SMR projects at such sites, engaging with the potential future host municipalities, the local residents and nearby industry. Such sites include the Taftøy-site in Heim and Aure municipalities, in the mid-region of Norway, situated adjacent to the existing Equinor Tjeldbergodden industrial facility (methanol plant, a gas receiving terminal and an air separation plant) and near the offshore O&G installations at Halten-fields, in need of substantial volumes of clean and reliable electricity, and where heat may be utilized for production of hydrogen or hydrogen derivatives, and CCS/CCU. The site anticipated for the SMRs is large enough to host several SMRs totaling at least 1,500 MW of electrical production, which is estimated to be near sufficient for local needs. The electrification of the Halten-fields and Tjeldbergodden have estimated a need for 275 and 480 MW of electricity respectively, while other industries nearby have estimated needs of approximately 1,080 MW, 1,835 MW in total. If all of these needs, or even additional needs, are realized, there’s sufficient land in the surrounding area to facilitate these.

 Additionally, projects at sites north of the city of Bergen, in the municipalities of Øygarden and Austrheim, and near the offshore O&G Troll-field, are in the early planning phases by Norsk Kjernekraft. The municipalities of Øygarden and Austrheim are also home to onshore petroleum installations, the Equinor Kollsnes gas processing plant and the Equinor Mongstad Oil Refinery, respectively. Sites in both municipalities are sufficiently large to host several GW of installed electrical production. The Transmission System Operator (TSO) of Norway, Statnett, has also already begun expanding the grid capacity connecting these two sites, so that situating in either municipality may facilitate the partial or full electrification of the offshore and onshore O&G installations, as well as other industrial expansions planned for the area. The latter includes potential CCS, clean steel manufacturing, establishing of datacenters, and hydrogen production to be transported via existing pipelines to Germany to aid their ambitions of utilizing hydrogen as a substitute for natural gas [11]. The early phases of Norsk Kjernekraft’s project in Austrheim has already attracted global partners, the South-Korean based DL Energy and DL E&C, enabling the utilization of existing expertise in the nuclear domain.

 Further prospects are plentiful, including the onshore Hammerfest LNG facility in Finnmark county, northern Norway and the associated offshore Snøhvit-field installations in the Barents Sea, the Kårstø processing facility in Rogaland county, south-west Norway, and connected offshore fields of Statfjord, Gullfaks, Sleipner, and Åsgard, as well as many others.

## UTILIZING THE EXISTING O&G WORKFORCE

The Norwegian O&G sector employs, directly and indirectly, around 200,000 workers, a significant share of the total Norwegian workforce. Many of the businesses, functions and competencies employed in the O&G sector may directly, indirectly, or, after some additional education, training and qualification, be applicable to the nuclear sector, in planning, licensing, design, construction, manufacturing, operation and servicing SMRs. Particularly, staff that’s been working as higher management, managers and supervisors, control room operators, mechanical-, electrical- and I&C-maintenance, and station engineering all have a solid basic training level.

 As the need for O&G may decline in the coming decades, if GHG-policies are implemented, there’s ample room for a significant share of these roughly 200,000 workers to enter the nuclear sector. As there’s generally a high demand for human resources in the global nuclear industry already, there are significant market opportunities for newcomers from fields of particular relevance, such as the O&G sector. The growing global nuclear industry also provides ample opportunities for Norwegian industry such that nuclear industry experience may be attained even before Norway implements its first SMRs.

 Other Norwegian industry segments, such as the maritime and process industries, closely integrated to the O&G sector, are also well positioned to support a nuclear industry, of which there’s particular historical precedence in our neighboring country, Sweden, where, in the 70s, staff from shipping and other process industries were attracted to the new and expanding business of nuclear power.

The prospects of exploring nuclear propulsion in ships to reach the International Maritime Organizations’ goal of net zero around 2050 has manifested Norwegian-led international initiatives such as an OSM Thome-led pilot-project “Grønt skipsfartsprogram” [12] and the Norwegian University of Science and Technology led project NUPROSHIP [13], investigating the use of SMRs, highlighting it’s huge potential for Norwegian shipping and O&G actors as part of the green shift away from fossil fuels.

Today, Norway, Estonia, Poland, and several other countries, are exploring the prospects of reschooling personnel from other industries, particularly O&G. In Norway, Norsk Kjernekraft has already embarked on developing reschooling strategies, entering promising discussions with large O&G-companies, and several counties are exploring the establishment of nuclear engineering educational and training programs.

## CONCLUSION

Norway is advantageously positioned to implement SMRs to transition its O&G sector into a more sustainable industry while bringing significant local benefits. Norway has already the necessary legal and regulatory infrastructure in place, an independent regulatory body, and, being one of the first countries in world to implement nuclear reactors, a long history within the nuclear domain.

 Importantly, the public perception of nuclear power has been improving at an extraordinary pace, a broad national political support is developing, and key industrial entities have gained a renewed interest in the power source, setting the stage for tremendous capital resources to be directed towards its implementation.

 The business case for deploying SMRs for the electrification of O&G installations is solid, with estimated NPVs of several hundred million Euros per SMR. There’s a tremendous need for clean and reliable electricity in Norway, and the investment threshold is similar to a medium sized oil field, but with significantly lower risks and with prospects for further added asset values through heat utilization and future uprates. The business case is further aided significantly by prospects of utilizing generous tax deduction mechanisms, enabled through the Petroleum Taxation Act. Such mechanisms may also further aid significant deployments of capital into a Norwegian SMR venture, fostering the utilization of SMRs to reduce industrial GHG emissions, as well as securing growth and sustainable development for existing Norwegian industries. Many potential SMR sites of Norsk Kjernekraft, now in the early development stages, are suitable for not only enabling a more sustainable O&G industry but also facilitating other clean industries such as production and transportation of hydrogen and hydrogen derivatives, production of food, CCS/CCU, clean steel manufacturing, low carbon datacenters and many others.

 As there are many similarities between the expertise and supply chains needed in the nuclear industry and the O&G industry, ample opportunities for synergies between the two sectors naturally arise. Furthermore, as there is already a growing need in the nuclear industry for strengthening supply chains and increasing human resources, while at the same time the need for O&G may decline in the coming decades, companies in the O&G industries are advised to as soon as possible explore opportunities in the growing nuclear domain.

As such, Norway, with its particularly good conditions for enabling SMR deployments, may provide excellent examples for other countries to follow in the coming decades as to how more sustainable O&G production may be achieved, and subsequently utilizing these achievements to further transition to net-zero societies.

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