The Research Council of Norway

# OG21 Report on Low-emission Technologies

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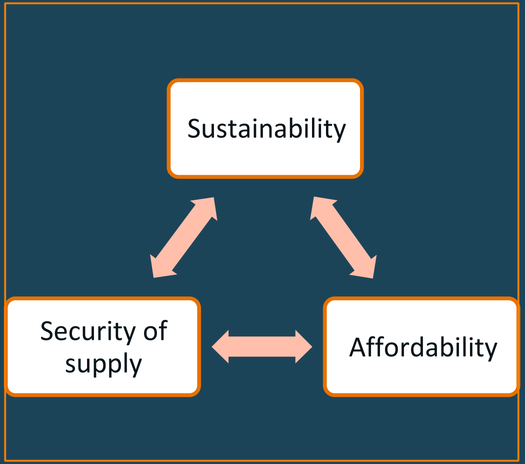
OG21

# Summary, conclusions and recommendations

# Summary – De-carbonization must continue also in times of energy crisis

- The geopolitical importance of energy has become ever more apparent as the Russian invasion war on Ukraine has evolved. Energy is used as leverage in Western sanctions on Russia, and Russia has cut natural gas supplies to Europe to weaken European support for the Ukrainian resistance war. The energy crisis playing out in Europe underpins that a well-functioning energy systems needs to provide energy that is affordable, sustainable and with a high security of supply. All three elements are challenged as Europe struggles to cope with energy scarcity, high prices, and a more severe threat situation for critical energy infrastructure.
- The Ukraine war adds uncertainty to an already uncertain energy future. The development of the demand for various energy carriers will depend on how successfully the global community is at curbing GHG emission, which again hinges on collaboration, policies, investments, and scaling of low-carbon technologies. Oil and gas will continue to be a vital part of the energy systems throughout the energy transition, but petroleum producers must be prepared for high price volatility around a declining price trend if the world succeeds with the transition.
- Within this picture, the OG21 Strategy from 2021 with its three pillars, is still highly relevant:
  1. Compete efficiently for oil and gas market shares. This requires a host of new technologies to bring costs down, find and mature new resources, reduce GHG emissions, and maintain a high safety level.
  2. Secure future markets by de-carbonizing the use of petroleum, and especially natural gas.
  3. Continue to develop knowledge and technology in the petroleum sector that can also be used in the creation of new industries.
- Reducing GHG emissions has become an integral part of being competitive. It is important for attracting investments, it is required for maintaining society's acceptance, and it increasingly important for retaining and recruiting talent.
- Norway has set ambitious goals for reducing GHG emissions, among those is a 50%-55% reduction by 2030. The petroleum sector is responsible for around 25% of Norway's total emissions, and the goal of reducing emissions in this sector with 50% by 2030 is therefore important for Norway to meet its goals.
- Two recent reports from Konkraft and Miljødirektoratet, respectively, suggest that the petroleum industry's goal for 2030 is challenging, but achievable. Electrification from shore is by far the single most important measure.
- Many other sectors and industries also need more electrical power to de-carbonize, and Norway is heading towards a situation with electrical power surplus approaching zero before year 2030. Electrification of offshore installations from shore is therefore increasingly being challenged.
- This is the backdrop for this year's OG21 deep-dive study. OG21 has in collaboration with DNV investigated how electrification of the NCS could be done efficiently and with less demand for onshore power, and whether the implementation of other promising GHG reduction technologies could be accelerated within the 2030-time frame.

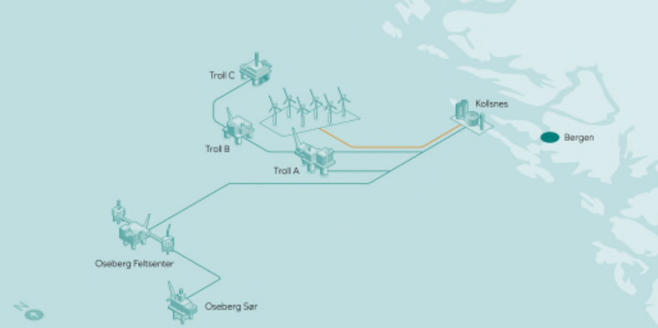
The energy trilemma plays out amid a global energy crisis



# Conclusions – Electrification is crucial to reduce NCS emissions. Electrification with wind power and gas power with CCS should have a more significant role.

- The near-term GHG emission target of 50% reduction by 2030 compared to the 2005-level is achievable. Four types of technologies are especially important to meet the target:
  1. **Electrification from shore** is crucial to meet the 2030 GHG emission target for the petroleum industry. It is important that the electrification is done as efficiently as possible and with flexibility for future integration with the bigger energy system. The industry has already successfully established area solutions with collaboration between production licenses. Such collaboration will be important going forward. Cables and distribution hubs should be designed to allow for integration with offshore wind and/or low-emission gas power, and for exchanging power in both directions with the onshore grid.
  2. **Electrification with offshore wind** could be developed faster and have significant contributions to GHG reductions by 2030. Offshore wind projects isolated from the onshore grid and serving a few installations (e.g. Hywind Tampen) are important for technology scaling and experience gathering. However, since back-up gas turbines are needed for periods with little wind, the GHG emission reductions are smaller than for offshore wind integrated with larger grid systems. An offshore wind farm integrated with the onshore grid, could feed several offshore installations as well as the onshore grid with renewable energy.
  3. **Electrification with low-emission gas power hubs** could be developed faster and have significant contributions to GHG reductions by 2030. Low-emission gas power hubs, which are gas power plants with CCS, could be placed either offshore or onshore. Several offshore concepts exist on the drawing board, utilizing mostly mature technology elements, whereas the onshore solution would be conventional combined-cycle gas turbine plants combined with CCS. Costs are expected to be lower for onshore concepts.
  4. **Energy efficiency** continues to be a priority for the industry spanning all technical disciplines. With the close connection between energy use and GHG emissions, all opportunities for saving energy must be examined. Water management is an area of particular interest – a lot of energy is used to pump water from the well to the topside, separate water from the wellstream, and pump water back either for storing or pressure support. Measures to improve reservoir drainage with less water production, well completion to shut off water early, water separation in-well or at the sea bottom, are all examples of technologies that could reduce one of the biggest contributors to energy use and GHG emissions offshore.
- Abatement costs for electrification projects are typically 1000-3000 NOK/ tonne $CO_2$ as compared to a CO2-price of 2000 NOK/tonne $CO_2$ expected in 2030. Many electrification projects are as such profitable, but the industry needs to bring costs further down to mature sufficient projects to meet the 2030 GHG reduction target. Both offshore floating wind and gas power with CCS are currently more expensive electrification alternatives than power from shore, but costs are expected to decrease over time in line with traditional cost learning curves.
- The threat situation for Norwegian energy infrastructure has increased. This calls for a heightened preparedness level and increased efforts to identify and manage sabotage risks.
- Reducing Scope 3 emissions is important to maintain society's support for petroleum activities, maintain attractiveness for investors who increasingly weigh in climate risk in their portfolios, attract and retain talent, secure the future market for natural gas, and create new valuable industries for Norway. Norway therefore needs to continue R&D&I efforts to establish value chains for CCS and blue hydrogen.

The Trollvind concept (ref.Equinor)




The "Blå strøm" concept (ref.blåstrøm.no

# Recommendations

**#1 –Electrification from shore is crucial to meet the 2030 GHG emission target for the petroleum industry.**

- Power-from-shore is key to reach both the national and the industry's 2030 GHG targets. This message must be reiterated regularly.
- Electrification needs to be done as efficiently as possible and with flexibility for future integration with the bigger energy system. New radial connections should allow for integration in an offshore grid at a later stage.
- Cables and substations should be designed to allow for integration with offshore wind and/or low-emission gas power, and for exchanging power with the onshore grid.
- The industry should continue to seek area solutions and collaboration between production licenses. A coordinated approach on power from shore, low-emission gas power hubs, and offshore wind farms, can lay the foundation for a future meshed offshore grid. This will increase the redundancy and be part of a basis for development of new ocean industries.

**#2 –Electrification with offshore wind and offshore or onshore low-emission gas power hubs should be developed faster to provide significant contributions to GHG reductions by 2030.**

- Robust frameworks for offshore wind development and clarity in the basis for competition need to be in place to provide long-term investment signals and stimulate deployment.
- Clarity is needed in tax regimes for cross-over license areas between new industry (such as offshore wind or low-emission gas power hubs) and O&G assets, and how connections to the grid would impact this.
- The 30 GW target for offshore wind is an important first step. The target should be supported by a licensing and development roadmap.
- OG21 supports the measures suggested by Konkraft:
  - Contracts for difference; establish $CO_2$-fund; continue NOx-fund.
  - Norwegian authorities taking an active role in EU's work with development of frameworks for hybrid projects and the future masked offshore grid in the North Sea.

**#3 –Energy efficiency continues to be a top priority.**

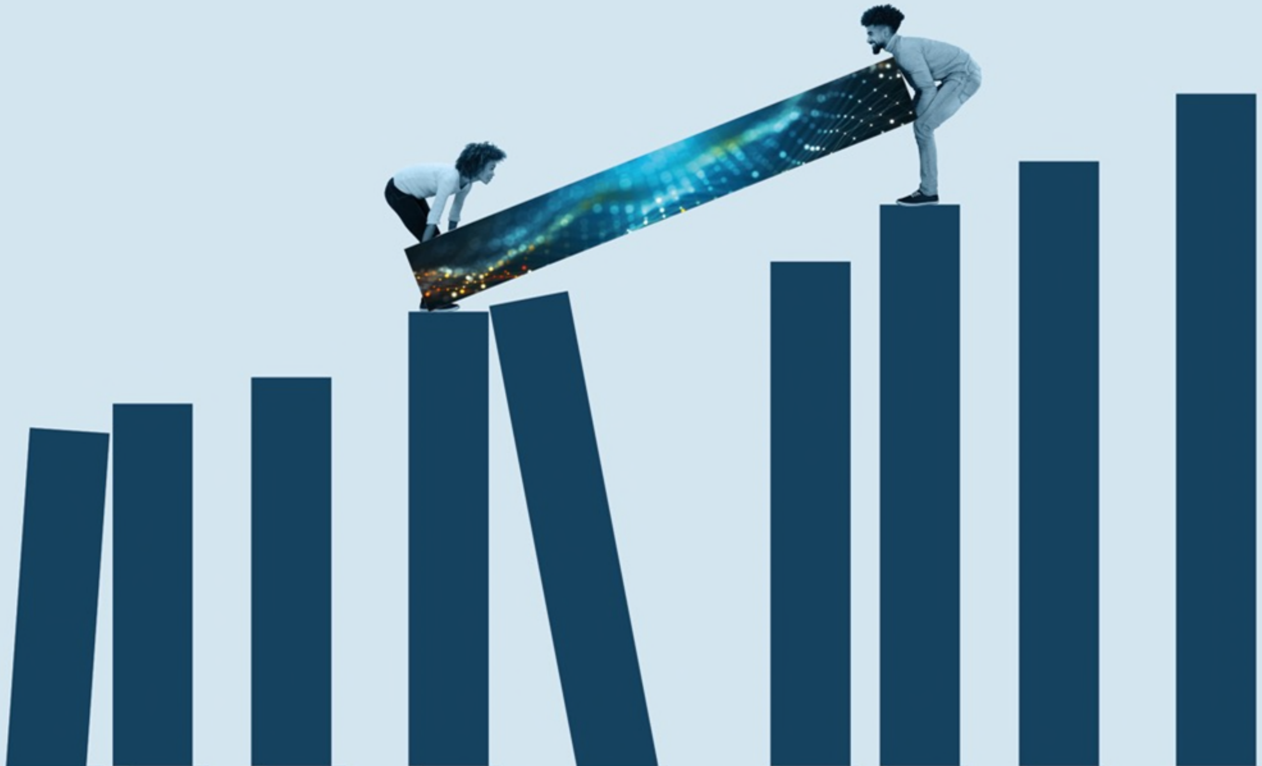
- Energy is a scarce resource and must be used wisely. The industry has over many years identified and implemented measures to conserve or reduce energy use. Such efforts must continue as offshore petroleum installations increasingly become integrated with the onshore power grid through electrification.
- Energy efficiency is a big bucket of measures where the cumulative contribution of all make a big total difference. The approach therefore needs to be holistic.
- Within the holistic approach, the big energy consumers need specific attention. Water management from the reservoir to topside is a major opportunity for reducing energy use, including:
  - Improved subsurface understanding and technology to place wells better and drain reservoirs with less energy use.
  - Smart well completion to stop water inflow.
  - Water treatment at low elevation to avoid lifting of water to topside, e.g downhole or seabed separation and re-injection.
  - Optimal use of topside water separation and re-injection equipment.

**#4 – No time for complacency, industry and regulators must act now:**

- It is time-critical to mature sufficient GHG emission reduction projects to deliver on the 2030 target. Permitting, equipment delivery, and project execution all take time. The industry needs to rapidly identify and mature more projects through the feasibility and concept stages to reduce uncertainty on whether the 2030-targets will be met.
- Regulators should look at ways to speed up decision processes for licensing and permitting of GHG emission reduction projects.
- New $CO_2$ storage sites should be developed in parallel, and more license areas should be allocated. OG21 supports Konkraft's suggestion for establishing concrete targets for how much $CO_2$ should be stored on the NCS.
- The close monitoring and reporting of progress managed by Konkraft is important. If progress is not satisfactory, industry needs to react fast and implement more emission reduction measures to avoid increased $CO_2$-tax or other regulatory actions.
- Norway should increase its ambitions on development and implementation of clean technologies to position Norwegian industry and ensure a competitive advantage.
- Innovation can reduce cost and speed up the transition. R&D programs such as Petromaks2. Demo2000, Climit and Petrocenters should be strengthened.
- Long-term decarbonization must not be forgotten while striving to meet 2030 targets. R&D&I efforts on low-carbon energy carriers such as offshore wind, hydrogen and hydrogen-derived fuels, must continue.

# Content

# 1. Background, purpose and scope



# Background, purpose and scope

**On OG21:**

OG21 has its mandate from the Norwegian Ministry of Petroleum and Energy (MPE). The purpose of OG21 is to "contribute to efficient and environmentally friendly value creation from the Norwegian oil and gas resources through a coordinated engagement of the Norwegian petroleum cluster within education, research, development, demonstration and commercialization. OG21 will inspire the development and use of better skills and technology".

OG21 brings together oil companies, universities, research institutes, suppliers, regulators and public bodies to develop a national petroleum technology strategy for Norway.

Based on its mandate from the Norwegian Ministry of Petroleum and Energy, OG21 develops and maintains the technology strategy for the Norwegian petroleum industry.

The OG21 strategy was last updated in November 2021.

**On the project:**

The new OG21 strategy, launched in November 2021, describes a need for reducing GHG emissions in the petroleum production phase as well as along value chains, as an essential part of maintaining competitiveness.

The main measure to meet the 2030 GHG emission targets is electrification from shore. Prognoses do however show that the widespread electrification of the society as well as the establishment of new power-consuming industries, could cause the power surplus to approach zero before year 2030. This in combination with high electricity prices in 2021/2022, has sparked a political debate on the power grid development, power interconnectors with other countries, as well as on the pace of the NCS electrification.

OG21 therefore wanted to investigate how electrification of the NCS could be done efficiently and with less demand for onshore power, and whether the implementation of other promising GHG reduction technologies could be accelerated within the 2030 time frame.

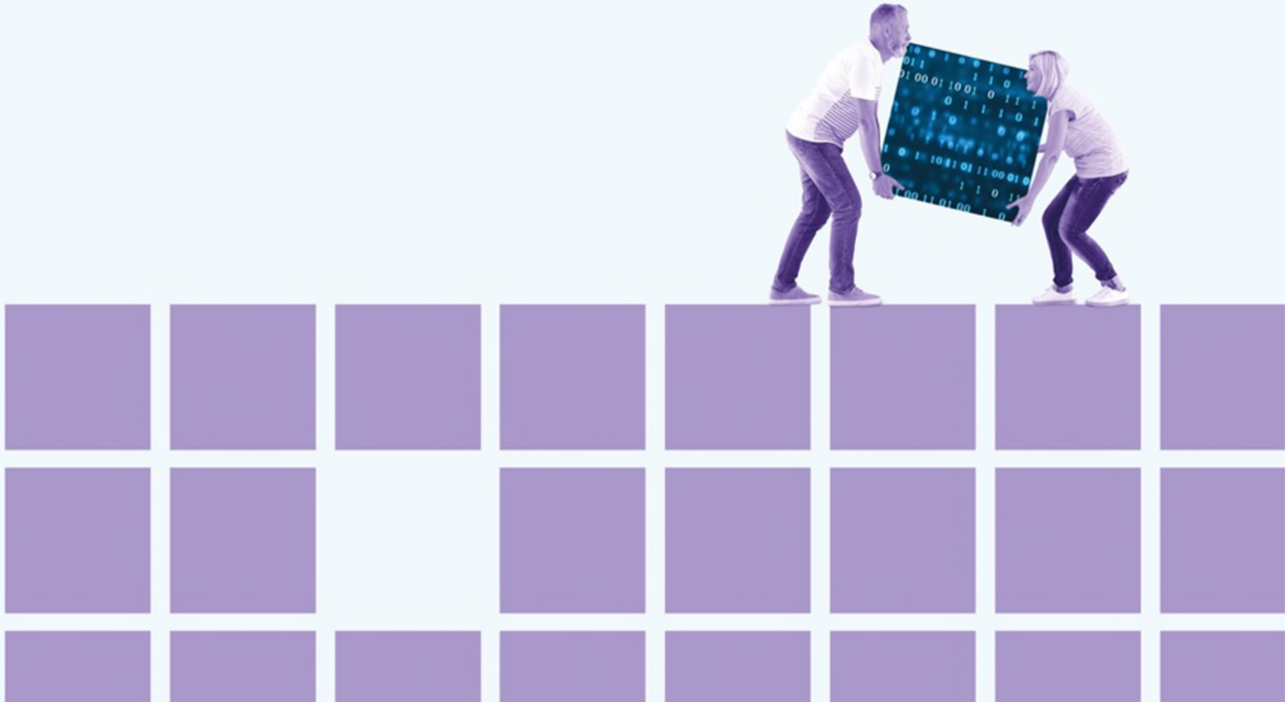
**On the DNV report:**

The OG21-project included the commission of a study from DNV. The DNV report is available on the OG21 website.

The report from DNV is based on in-depth interviews with stakeholders in the Norwegian petroleum industry, literature studies, in-house research and results from several OG21 workshops conducted as part of this OG21-project.

The DNV report is the main basis for the OG21 report. Where other sources of information have been used, these are referred to in the standard scientific reference notation.

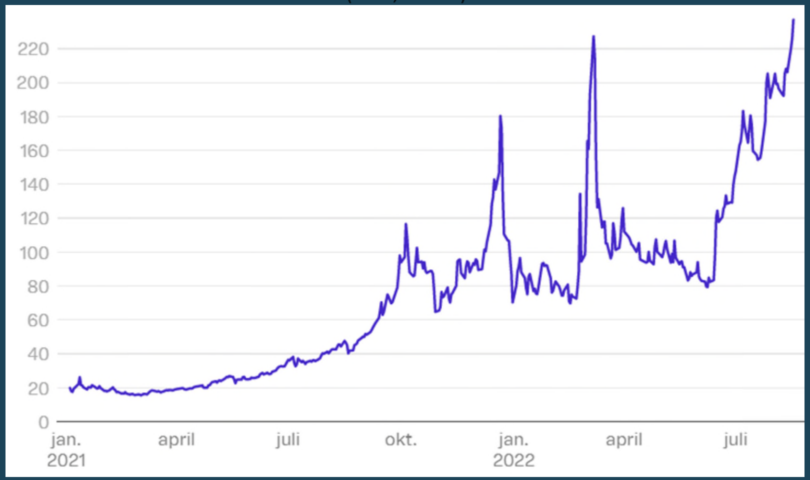
# 2. The energy situation and Norway as a reliable energy provider



# 2.1 A tight energy supply has evolved into an energy crisis

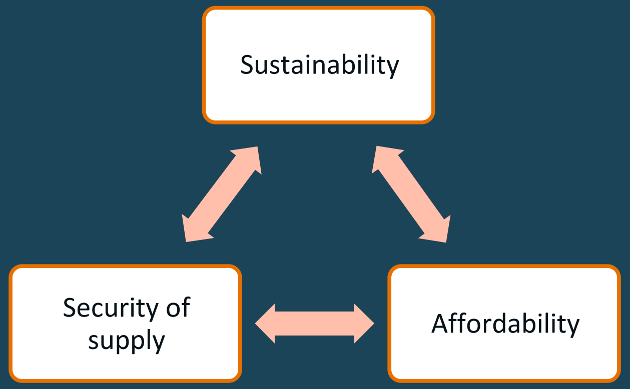
- A tight energy market in Europe, as the region was recovering from Covid-19, was further tightened by Russia's unjustified reductions of gas supplies in the last quarter of 2021 in advance of its invasion of Ukraine (Birol, 2022). The result was historically high gas prices in Europe already prior to the Ukraine war.
- The strong sector coupling between natural gas and electrical power has, in combination with a drought and low hydropower production as well as unplanned downtime for nuclear power in France, contributed to also record-high electricity prices across Europe throughout 2022.
- Natural gas has become a weapon in the geopolitical conflict between Western countries and Russia in the aftermath of the Russian invasion of Ukraine in February 2022. Western countries have imposed economic sanctions on Russia, and Russia have responded with technical and legal actions. Some of the escalating actions are:
    - Germany decision not to open North Stream 2 in March.
    - The REPowerEU plan launched in March to become independent of Russian natural gas before 2030. Further detailed in May.
    - Russia cutting supplies of gas to countries refusing to pay with roubles.
    - “Save gas for a safe winter” plan proposed by the European Commission in July.
    - Russia reducing supplies through the North Stream 1 pipeline in July to 20% of capacity, blaming Western sanctions.
    - Russia stopping all export through North Stream 1 in September.
    - Sabotage action, unknown by whom, against Nord Stream 1 and 2 on September 27th impairing gas delivery through those pipelines for a long time.
- Russia is obviously willing to sacrifice revenue from its natural gas sales to the European market both short and longer term. Natural gas is however considerably less important than oil for Russian petroleum revenue. Oil sales is only modestly impacted by Western sanctions so far, and any lost market share or need to sell oil at discounted price, is more than offset by the increase in oil prices since the outbreak of the war.
- Further uncertainty to global energy markets could play out around and after December 5th. The EU’s boycott of Russian oil then comes into action. An important element of the boycott is the ban on insurance of Russian oil cargoes which could impact Russia’s ability to sell oil also to other markets than the European. The G7-countries have agreed to set a price ceiling for Russian oil from the same date, aimed at curbing Russian oil income.

Natural gas price (TTF) for future delivery. Euro per megawatthour (E24, 2022)

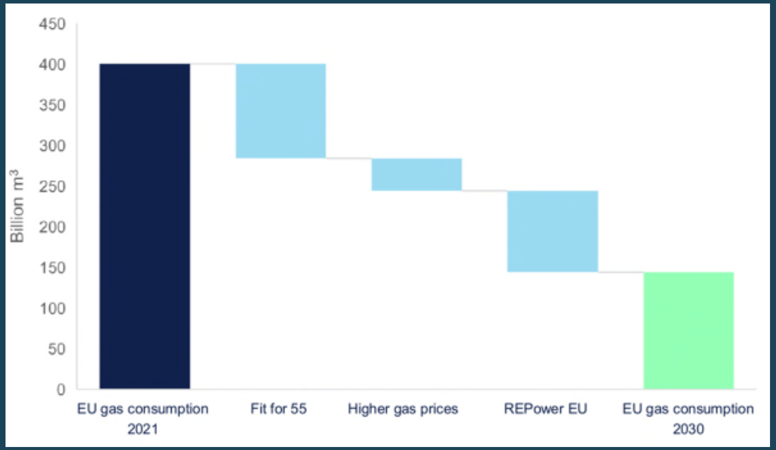



# 2.2 Norway's role as an important energy partner to EU is strengthened

- The REPowerEU plan to become independent of Russian fossil fuels and accelerate renewables, addresses the energy trilemma challenge: providing energy that is affordable, sustainable and with a high security of supply.
- The plan includes actions on topics such as energy efficiency for consumers, decarbonizing industry, speeding up renewables and improve grid infrastructure, and accelerate the use of renewable hydrogen. Norway could assist EU on a number of these, e.g. with offshore wind, low-carbon hydrogen, and CCS.
- The most important role for Norway to help EU delivering on the plan, is however to provide as much natural gas as possible to EU in the years to come. Russia provided 155 bcm or approximately 40% of the natural gas consumed by EU in 2021, and EU wants to have this replaced with LNG and piped gas from reliable providers as soon as possible.
- Even if demand for Norwegian gas is increasing, at least in the short term, the REPowerEU plan is aiming at reducing the overall use of natural gas in EU. This is in line with the general Green Deal strategy, where especially the rules and regulation package "Fit for 55", aims at replacing natural gas use with renewables. In addition to REPowerEU and "Fit for 55", the higher gas prices will also lead to gas being substituted (unfortunately this is likely to be with coal). By 2030, EU estimates that the natural gas consumption could be as low as 150 bcm. By comparison, Norway delivered 90 bcm natural gas to EU in 2021. Within this demand scenario, there should be ample room for Norwegian gas towards 2030. After 2030, when EU continues its strive to de-carbonize, the natural gas demand would continue to decline. LNG, which is more costly and with higher $CO_2$-emissions, is likely to be out-competed by piped gas during the transition. However, at some point in time well before 2050, also natural gas delivered by pipeline must be expected to be replaced with low-emission energy.
- Norwegian natural gas has got an expanded time window as a result of the Ukraine war. Norway should nevertheless continue to explore for ways to market its natural gas with near-zero emissions. This includes continued efforts to develop the CCS value chain as well as safe and cost- and energy-efficient blue hydrogen value chains.
- The threat situation for Norwegian energy infrastructure has increased as a result of: (i) the increased relative importance of Norwegian natural gas to the European energy system, and (ii) recent major disruption events to critical energy infrastructure (the sabotage against the Nord Stream pipelines in September 2022, and the cyber attack on the Colonial pipeline in May 2021). This calls for a heightened preparedness level and increased efforts to identify and manage sabotage risks.



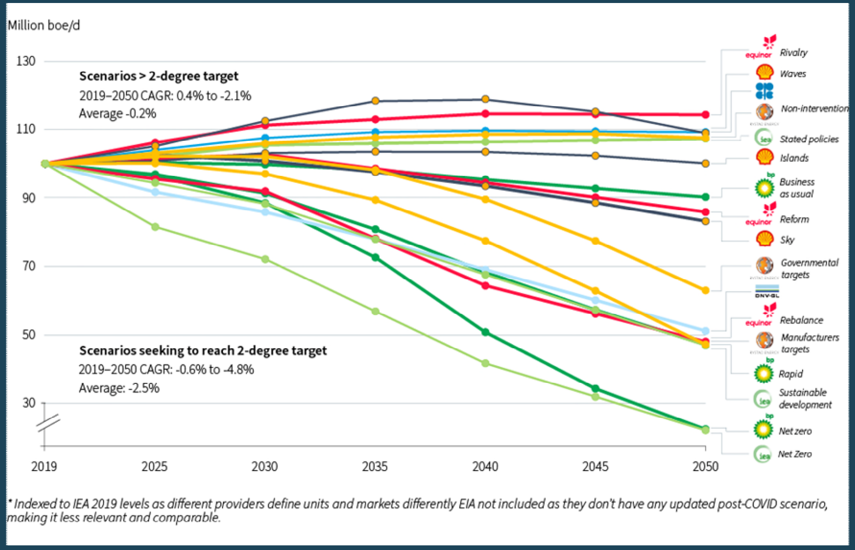

Estimated gas demand reduction towards 2030 (Energi og klima, 2022)



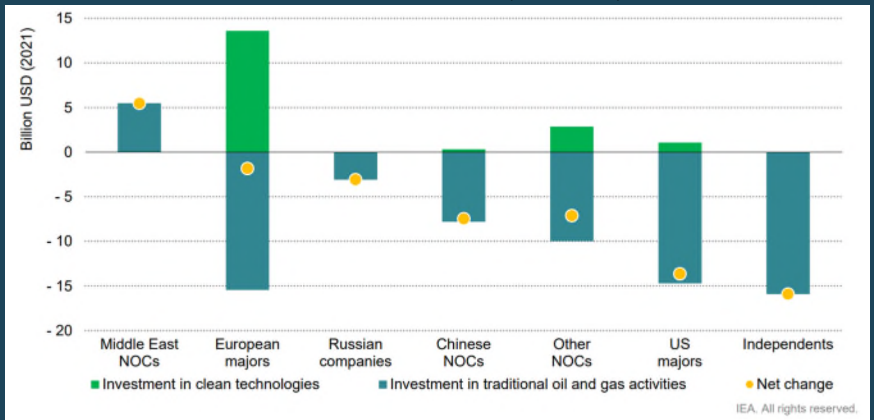
# 2.3 The world needs petroleum amidst a climate crisis

- The Ukraine war has added uncertainty to an already very uncertain energy future. OG21 presented a compilation of demand scenarios in the OG21 Strategy (2021) which showed that future oil and gas demand depends heavily on whether the global community succeeds in curbing GHG emissions by scaling up low-emission energy sources.
- Recent publications from working groups contributing to IPCC's Sixth Assessment Report, show that curbing GHG emissions is more urgent than ever.
- As described in the OG21 Strategy, OG21 believes that an orderly energy transition needs to be realized through demand destruction caused by new energy sources outcompeting fossil fuels, and not by supply cuts. The supply shock resulting from the Ukraine war illustrates challenges with supply disruptions.
- The post-pandemic recovery since the summer of 2021 revealed an under-investment globally in all sorts of energy, including oil and gas. According to IEA, only Middle East National Oil Companies (NOCs) plan to spend more on traditional oil and gas in 2022 as compared to 2019 - all other types of oil and gas companies plan to spend less. A report from the International Energy Forum and IHS Markit shows that Oil and Gas investments would need to increase significantly towards 2030 in order to balance the markets, even in a scenario with a plateaued demand.
- This illustrates the counter-intuitive fact that oil and gas investments are needed in the energy transition to zero-emission societies. The transition will have to take time, meanwhile production from existing oil and gas production will not be able to meet demand unless new investments are made.
- Attracting new oil and gas investments is however becoming more difficult, especially for IOCs and independents. Investors are increasingly considering climate risk in their decisions. Low GHG emissions is therefore becoming a core competitive advantage.

Oil demand scenarios (OG21, 2021)



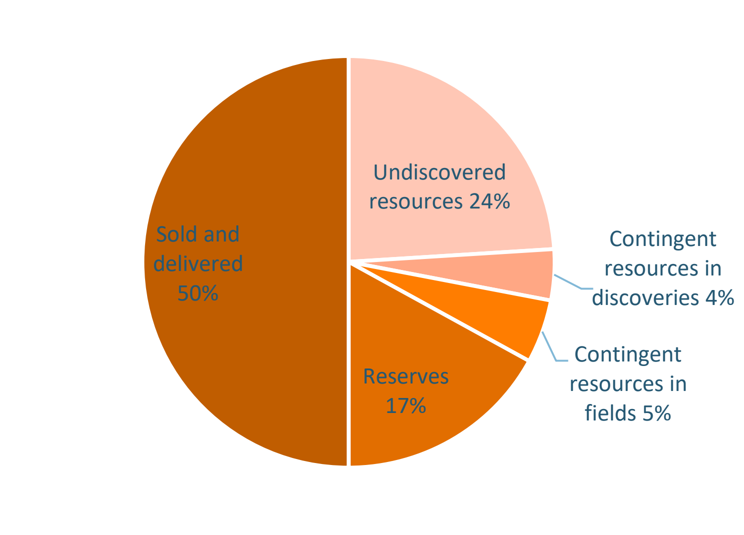

Change in investment by different groupings of oil and gas companies, 2022-estimate vs 2019 (IEA, 2022)

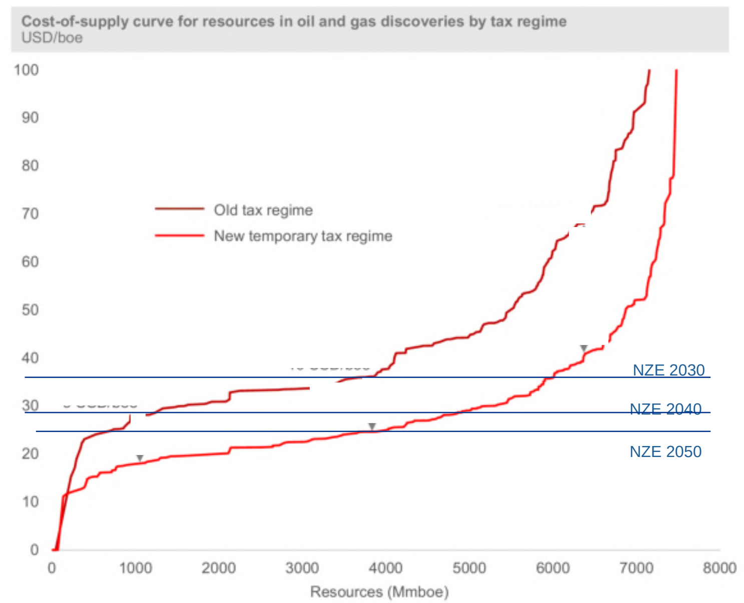


# 2.4 The OG21 strategy remains relevant – cutting GHG emissions is an essential part of staying competitive

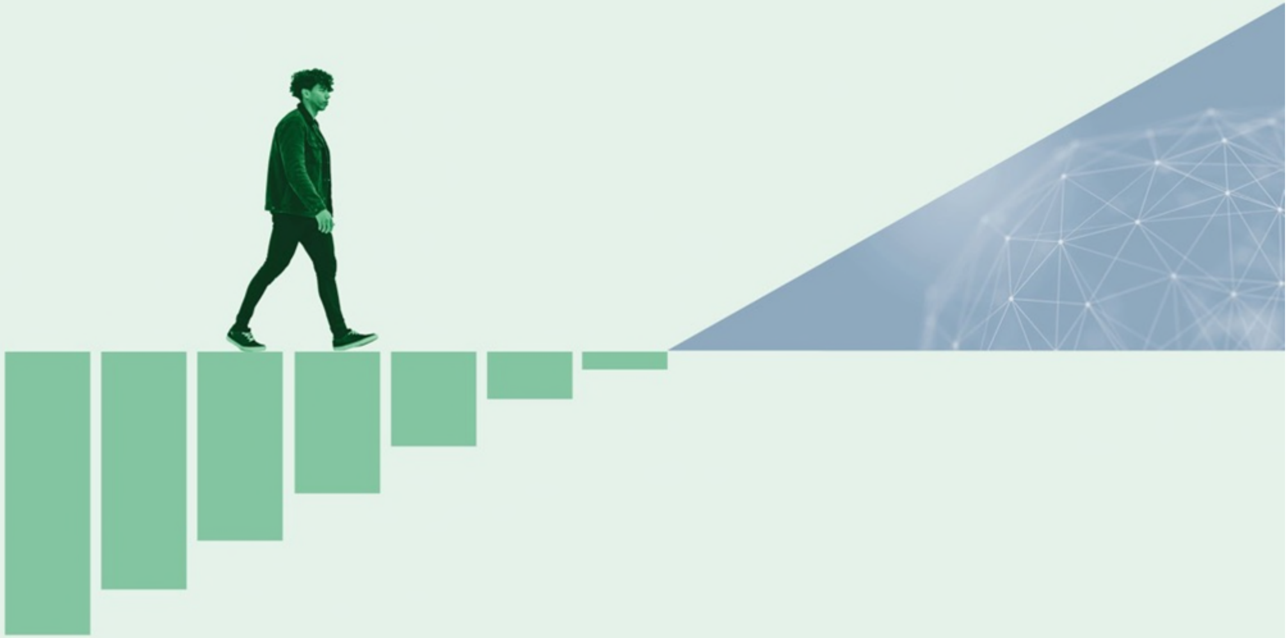
- The NCS still holds large resources of oil and gas. NPD estimates that only half of it has been produced (NPD, 2022).
- How much of the remaining resources that will be produced depends on many factors such as politics, stakeholder support, attracting investments and technology. Maintaining a high safety level and providing attractive frame conditions are fundamental for continued development of the NCS. Key competitive factors are low break-even prices and low $CO_2$-emissions.
- IEA published the Net Zero by 2050 (NZE) report in 2021 showing a path of how oil and gas demand would have to be reduced over the years towards 2050. The scenario is shown as the sharpest decline scenario among other scenarios on the previous page. On the graph to the lower right, the implied oil prices in the NZE report have been superimposed by OG21 on a cost-of-supply curve for the NZS produced by Rystad Energy. It implies that with the old tax regime, still 50% of the oil and gas resources in the discovery portfolio will be profitable in 2030, and that with the temporary tax regime 75% would be profitable.
- The discussion above and on the previous pages suggests that there is a market for oil and gas for many years to come, that the market development is highly uncertain, and that the energy transition is likely to reduce the demand for oil and gas over the next decades. The OG21-strategy published in 2021 is within this picture still highly relevant with its three pillars:
    1. Compete efficiently for oil and gas market shares. This requires a host of new technologies to bring costs down, find and mature new resources, reduce GHG emissions, and maintain a high safety level.
    2. Secure future markets by de-carbonize the use of petroleum, and especially natural gas. This requires the development of new value chains and technology for gas power with CCS and blue hydrogen.
    3. Continue to develop knowledge and technology in the petroleum sector that can also be used in the creation of new industries such as offshore wind, seabed minerals mining, and CCS as a service to other sectors.
- In addition to being the right thing to do, reducing GHG emissions has evolved to become a competitive advantage. It is needed to maintain society's support, attract investments, attract new talent, and keep the workforce motivated. The Norwegian petroleum industry has ambitious goals of reaching near-zero emissions by 2050 and reduce emissions with 50% by 2030 as compared to 2005-level (Konkraft, 2022). Electrification from shore is the most important element near-term. This is however being challenged by many since an increased electrical power demand also from the rest of the society, could lead to a deficit in electrical power supply before 2030. This is the background for the study OG21 conducts in 2022 on low-emission technologies.

NCS resources (NPD, 2022)



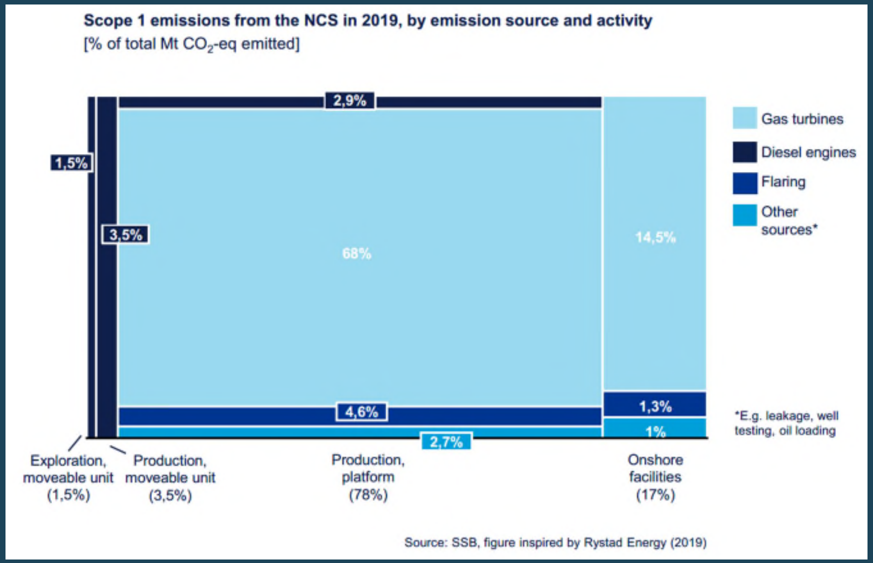



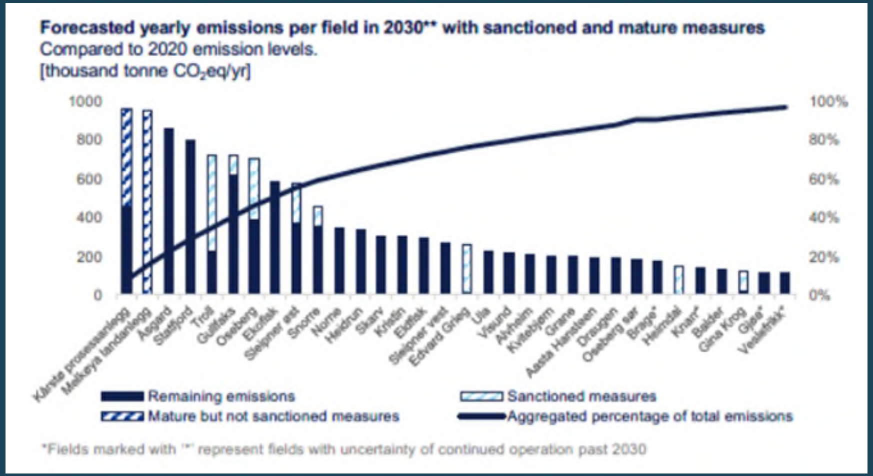
# 3. How to cut operational GHG emissions and meet industry targets



# 3.1 Petroleum industry is a major contributor to Norway's GHG emission, and gas turbines is the main culprit.

- The operational GHG emissions from the petroleum industry of approximately 12 million tonnes $CO_2$-eq./year, represent around 25% of Norway's total emissions.
- Gas turbines is the main contributor to the $CO_2$-emissions from the petroleum sector with 83% of the total, including the onshore facilities.
- 8 facilities contributed with more than 50% of the $CO_2$-emissions in 2020.
- Emission reduction actions should target the main emission sources. Operators and licensees of the largest emitting facilities have a special obligation to contribute to reduced $CO_2$-emissions. The OG21 Strategy describes several ways to reduce emissions from gas turbines, including:
    - Reduction of the power demand where energy efficiency is central. Energy efficiency includes a variety of measures such as to utilize heat in process streams for heating purposes or improvement of reservoir drainage methods.
    - Increase the efficiency of the turbines either by planning the operation so that the turbines can be run at higher efficiency level or by utilizing the heat in the flue gas.
    - Replace natural gas turbine fuel with low emission fuel such as blue or green hydrogen/ammonia.
    - Capture $CO_2$ from turbine flue gas and inject into underground reservoirs (local CCS).
    - Replace gas turbines with low-emission electric power. Several options are possible:
        - Power from the onshore grid, which is the historically preferred solution.
        - Power from offshore wind, which is now being tested at Hyvind Tampen.
        - Power from gas power hubs equipped with $CO_2$ capture and storage.

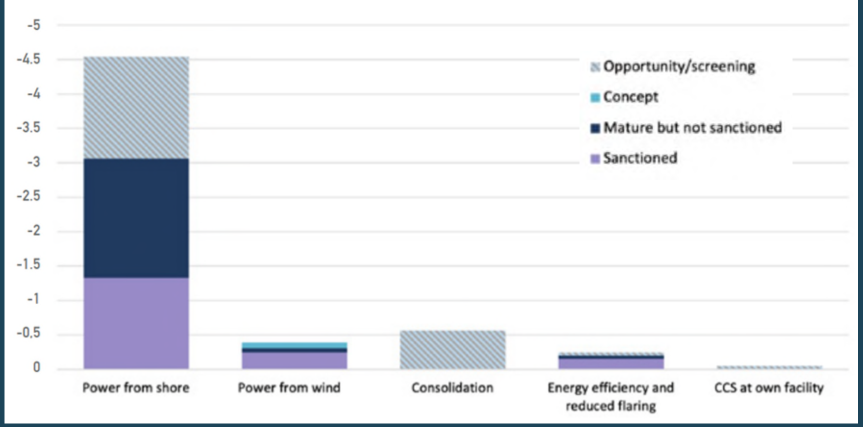


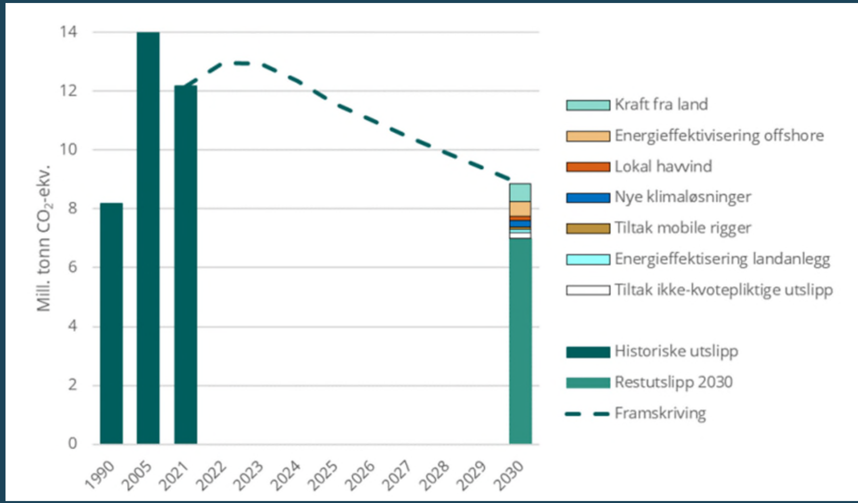
# 3.2 GHG emission targets are achievable. Electrification is the main measure. Increasingly challenged as electrical power surplus is diminishing.

- The petroleum industry has ambitious targets for reducing $CO_2$-emissions (Konkraft, 2022). The near-term goal originally set by Konkraft to 40% reductions as compared to the 2005-level, was sharpened to a 50% reductions expectation by the Parliament as part of the temporary tax agreement in 2020. The long-term goal is to have near-zero emissions by 2050.
- Konkraft describes power from shore as the main measure towards 2030 with a potential of reducing $CO_2$-emissions with 4.5 million tonnes or 33% of the 2005-level, including projects that are as early as in the screening phase. Power from offshore wind will in Konkraft's estimates have a limited effect towards 2030, mainly because the planned wind farms are connected directly to one and one installation. The wind power will therefore be variable, and gas turbines will remain a main power source. Consolidation is a group of project opportunities aimed at producing resources more efficiently for instance by re-routing well streams to other facilities or combining gas streams to utilize gas compressors more efficiently. CCS has only a modest effect towards 2030 according to Konkraft.
- A recent report from Miljødirektoratet (2022) largely confirms Konkraft's estimates. Miljødirektoratet has received input from the NPD to their report. In the report, already sanctioned and mature projects have been taken into account when estimating the $CO_2$-emission prognosis for 2030. This would represent a 37% reduction from the 2005-level. The remaining measures that needs to be taken before 2030 to meet a 50% reduction goal, would all be in concept and screening categories in the Konkraft terminology. Of these, power from shore and energy efficiency are the two biggest contributors.
- Based on the reports, electrification from shore stands out as the single most important measure near and mid-term towards 2030. Electrification from shore is however being challenged since Norway is heading towards a situation with electrical power surplus approaching zero before year 2030 as the society and other industries are being electrified.
- Electrifying more efficiently and accelerating other new low-emission technologies should therefore receive more attention. This is the background for the study OG21 conducts in 2022 on low-emission technologies.

Categorization of climate measures. Expected effects towards 2030. Abatement effect (million tonnes $CO_2$/y in 2030) (Konkraft, 2022)

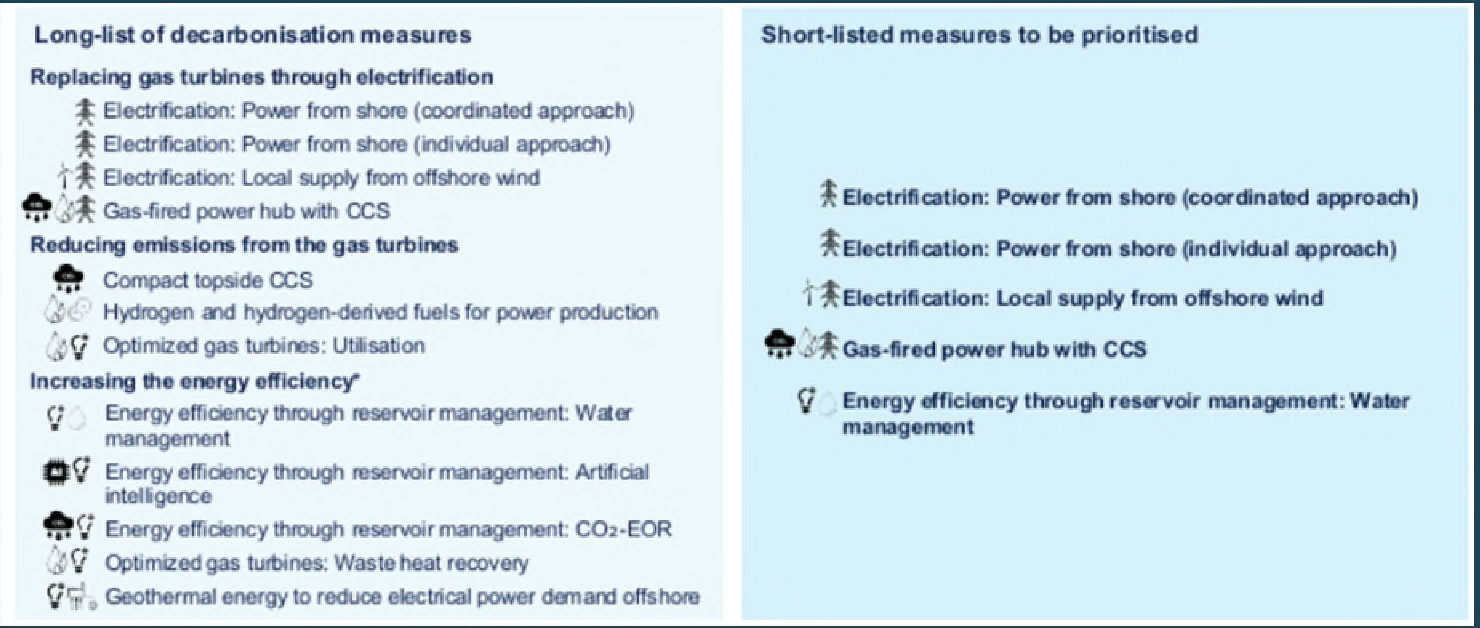



Historical emissions, prognoses and estimated effect of measures (Miljødirektoratet, 2022)



# 3.3 Main opportunities for reducing operational GHG emissions

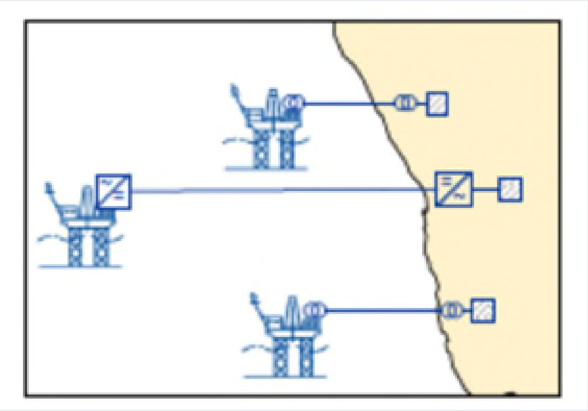
- The OG21 Strategy describes a host of important technologies to reduce operational GHG emissions, see Section 3.1.
- The list of opportunities was revisited as part of this study and a long-list was prepared by DNV as a basis for screening discussions with the OG21 technology groups (TGs).
- The screening of the long-list was based on the criteria:
  - GHG reduction potential
  - Maturity
  - Application scope and scaling potential.
  - Development and implementation obstacles
  - Industry opportunities and synergies
- The short-listed measures are as such the measures that DNV and OG21 believe could deliver large GHG reductions relatively fast (within the next 7-10 years).
- Energy efficiency is a large bucket of opportunities. All are important, but water management has been selected as an example with particular high potential.

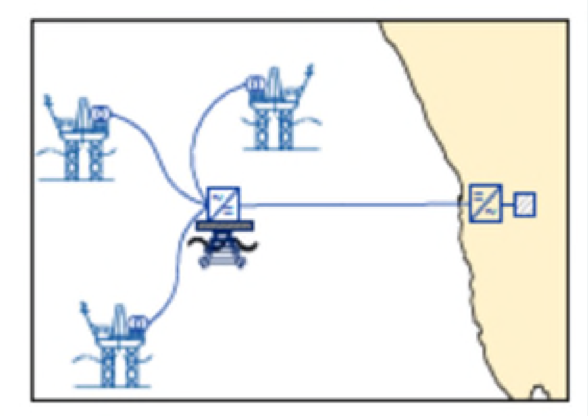


# 3.3.1 Electrification with power from shore

- OG21 shares the views expressed by DNV in the summary of their report (DNV, 2022):
  - *Electrification of O&G platforms through power from shore is considered a key measure to achieving the GHG emissions reduction targets, with an estimated total potential of 4.5 million tonnes $CO_2$e emission reduction per year in 2030. The preferred network design solution depends on several factors, and two fundamentally different options exist: an individual and a coordinated design approach.*
  - *Individual design approach: Each platform is connected to the onshore grid via a dedicated radial connection. This design offers simplicity and requires less coordination but can result in an overall sub-optimal network design and higher costs to ensure reliability of supply.*
  - *Coordinated design approach: Multiple platforms are connected to one offshore hub (shared substation) before being further connected to the onshore grid through a radial connection. Although this is a more complex design requiring a high degree of coordination between stakeholders, significant economics of scale and a more optimal network design overall can be achieved.*
  - *The main obstacles are related to distances from shore and weight and space limitations for DC equipment, high cost and loss of revenue related to full electrification, access to sufficient power from shore, as well as long lead times. For a coordinated approach, differences in remaining lifetime of assets and frequency levels are also important challenges.*
  - *Several mitigations exist on technical obstacles such as subsea or more compact equipment. On more political and societal obstacles, important mitigations include speeding up decision-making processes, establishing predictable policies and frameworks to give clear investment signals for offshore electrification, and building out new renewables and grid capacity.*
  - *Although electrification of platforms through power from shore is considered a key measure, anticipated reduction in power surplus and increased grid constraints, historically high power prices and continued domestic bidding zone price gaps, in additional to a challenging geopolitical landscape has caused a heated political debate on how the power grid should be developed and whether the NCS should be electrified from shore. This brings uncertainty to developers and operators. Long-term and predictable policies are crucial in reducing risks.*
  - *Electrification increases the energy efficiency, resulting in less energy use overall. Moreover, the operational costs can be reduced due to lower cost of $CO_2$ tax and fuel. Electrification of offshore assets will also have the indirect benefit of reduced noise and thereby improved working environment offshore.*
  - *The released natural gas can be exported to Europe and used in onshore gas power plants with higher efficiencies*. This will both increase export revenues for Norway while at the same time replacing European imports of natural gas with higher carbon footprint (i.e. LNG) and the use of coal.*

* OG21 remark: In addition to higher efficiency in onshore gas power plants, a significant portion of the gas delivered is used directly for heating and cooking with even higher thermal efficiency.





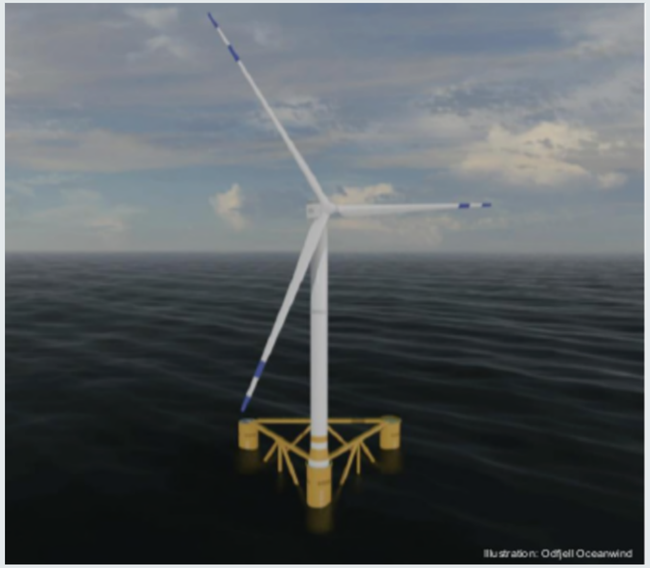
# 3.3.2 Electrification with offshore wind

- OG21 shares the views expressed by DNV in the summary of their report (DNV, 2022):
  - *Norway has excellent offshore wind resources and should act on the opportunity to take part in the global megatrend of offshore wind development.*
  - *O&G platforms could be supplied with electricity from offshore wind turbines without a connection to shore. As such, this solution can help provide electrical power to installations in areas with long distances to shore or where the onshore grid is constraint. However, this would require a back-up solution to ensure consistent power supply.*
  - *Offshore wind can be either bottom fixed or floating, however the water depth on the NCS suggests floating solutions are largely required. Floating wind is approaching large scale and commerciality, with only a few years before we will see the large multi unit-projects. Innovation and developments are still needed in order to reduce costs.*
  - *According to Konkraft, electrification through local supply from offshore wind is estimated to have a potential of 0.4 million tonnes of $CO_2e$ emission reductions per year in 2030 (based on reported measures). However, the potential can be much higher, especially in areas where electrification from shore is challenging. Installing a wind farm could also be an intermediate solutions until a cable from shore is in place.*[1]
  - *Supply chain constraints, long lead times and uncertain regulations are key obstacles for implementing offshore wind. In order to ensure predictability, it is important to speed up decision-making processes, develop local supply chains and coordinate developments across industries.*
  - *Combining power from shore with offshore wind can ensure security of supply as well as power supplied to shore during surplus hours. Technically, the power cable should be able to export back to the shore without major adjustment.*
  - *A combination of building out an offshore grid with power form shore and offshore wind farms to supply installations on the NCS has several industrial opportunities: developing floating offshore wind industry in Norway; ensuring security of supply to the installations and power supply to the onshore grid during surplus hours; facilitate a future meshed offshore grid that can connect to the planned North Sea offshore grid long-term; facilitate an offshore industry long-term when O&G assets are decommissioned.*
  - *Concepts of combining offshore wind with existing power-from-shore concepts, e.g. Utsira High or Troll West, can be especially relevant, as investments in transmission supply are already paid for. This can reduce OPEX from power purchases, limit total power losses through the transmission cables, while also give rise to fast-track medium-sized wind farms that could be important stepping stones to cost-efficient large-scale wind farms in the early 2030's. An important obstacle that should be further investigated is the uncertainty in regulatory frameworks for delivering power to shore under the Petroleum Tax Act*

OG21 remarks:

1. DNV quotes Konkraft correctly. OG21 shares the view that the ambition for offshore wind should be considerably higher than 0.4 million tonnes CO2-eq. per year. E.g. Trollvind alone with capacity 4.3 TWh could replace 20 gas turbines of 25 MW, which again represents 2.2 million tonnes CO2/yr.
(One 25 MW turbine ->25*8760=219 000 MWh/yr. One 25 MW gas turbine consume typically 10.4 MJ/kWh or 0.19 kg CH4 / kWh assuming heat value 1kg CH4 = 55,5 MJ. 1 kg CH4 produce 2.75 kg CO2. => 0.19*2.75 kg CO2/MWh *219 000 MWh/yr = 114 000 kg CO2 /yr = 0.11 million tonnes CO2/yr. 20*0.14=2.2 million tonnes CO2/yr)

Case: Odfjell Oceanwind



# 3.3.3 Gas power hubs with CCS

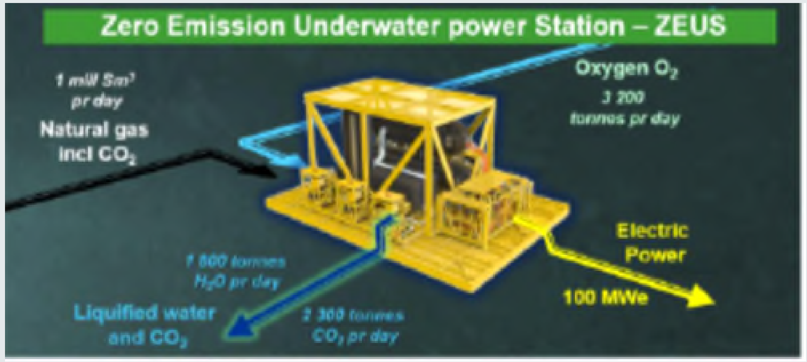
- OG21 shares the views expressed by DNV in the summary of their report (DNV, 2022):
  - *A gas-fired power plant with CCS provides electricity through running gas turbines while capturing and storing the $CO_2$. The plant could be located both onshore or offshore, and the preferred solution will depend on several factors (costs, available infrastructure, permits and regulation, political and societal acceptance, amongst others) which will depend on the given case.*[1]
  - *Several concepts have been developed, but none has been constructed to date. Use of qualified equipment as far as possible will be important in order to reduce risk and uncertainty.*
  - *An offshore power hub is a stand-alone solution independent of power from shore. As such, it can help provide electrical power to installations in areas with limited onshore infrastructure or long distances to shore. In the long term, the power hub could be connected to shore to supply additional power and balancing capabilities to the onshore grid. An onshore gas-fired power plant is in principle the same concept as power from shore but could help increase power production onshore.*
  - *DNV's analysis show that power hubs located in three areas could reduce emissions by 4.5 million tonnes $CO_2$e per year in 2030 (around 35 percent total reduction from 2020 levels), if all required infrastructure for transport and storage of $CO_2$ is in place.*
  - *A power hub requires many operators and stakeholders to agree on a solution and distribute cost and risk, so early dialogue and cooperation is key for getting this measure started.*
  - *The solution could help further develop the Norwegian CCS supply chain, cementing Norway as a global leader in CCS activities and commercial CCS value chains.*

OG21 remarks:

1. Costs would in most cases probably favor an onshore development, whereas permitting and system integration considerations could favor the offshore solutions. During the time since the DNV report was written, the geopolitical tension has further increased, which may make an onshore solution more attractive. It would make the facility easier to protect from intentional harm events and as such make the supply of power to offshore installations, to the onshore power grid, and to the power grid at our European energy partners, more resilient.

Case: Blå strøm

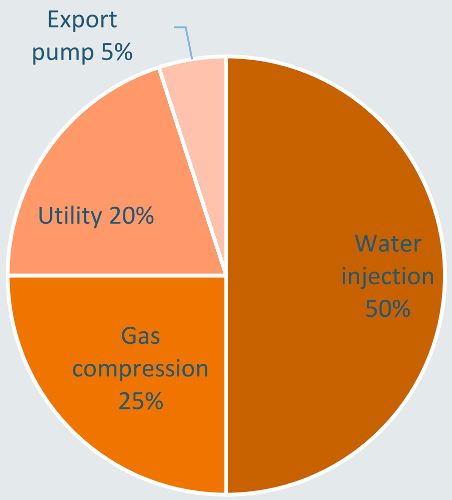
Case: Zeus

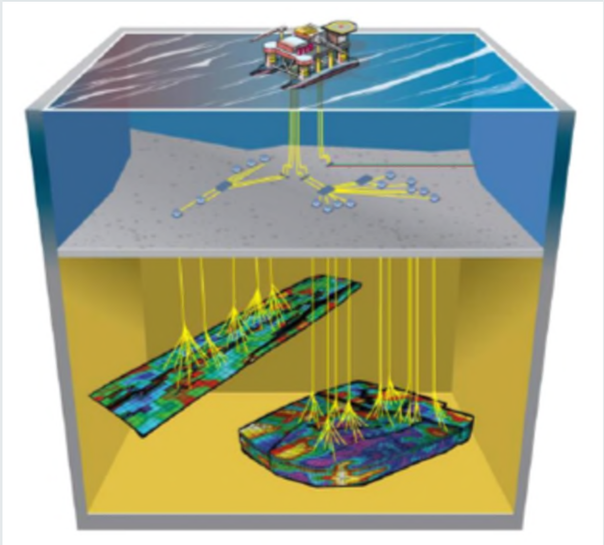


# 3.3.4 Energy efficiency through water management

- OG21 shares the views expressed by DNV in the summary of their report (DNV, 2022):
  - *With increasing energy cost and* $CO_2$ *price, the incentive for promoting new and improved technologies will increase. Co-operation between operators, vendors and expert areas is key to promote technology developments and remove silos.*
  - *The potential for energy optimization for water management stems from topside with optimal use of water pumps and compressors, subsea water treatment with separation and reinjection of water, and control of well inflow by smart completion. Choice of solution and resulting GHG emission potential is highly case sensitive, and the key to success for water management will be good reservoir understanding in combination with efficient use of data and technology.*
  - *The costs of new water displacement technologies are high. Standardization of technologies will bring down costs and risks, as will strengthening regulatory requirements to apply new technology in license and PDO-processes.*
  - *Several possibilities are available to limit water inflow and the energy used for water management.*
  - *The tail-end production with high water-cut wells is energy intensive. For the fields with the highest water-cut, shut-down of the fields might be a more economically viable solution taking a long-term industry perspective. If the industry is not progressing to meet GHG emission reduction targets, the government could respond by increasing the CO2 taxes and thereby reduce the long term value of all O&G industry production.*

Energy demand for typical oil field (Rystad Energy, 2019)



# 3.4 Abatement cost estimates

- Abatement costs for power-from-shore vary considerably from case-to-case. NPD reported in 2020 abatement costs of less than 1500 NOK/tonne $CO_2$ for four mature projects, whereas estimated abatement costs for immature or cancelled projects vary between 1000-8000 NOK/ tonne $CO_2$ (NPD, 2020).
- Miljødirektoratet (MD) has in a recent report, based on input from NPD, indicated abatement costs for power-from-shore projects in the range 1500-2500 NOK/ tonne $CO_2$ (KD, 2022).
- DNV has as part of the study for OG21, estimated abatement costs and LCOE (levelized cost of electricity) for four different generic electrification cases:
  - The power-from-shore case assumes a coordinated approach where one jacket-hub serving more installations. Abatement costs are estimated at 2 680 NOK / tonne $CO_2$, which is in the higher range as compared to the NPD and KD estimates.
  - Integration of floating offshore wind in combination with a coordinated supply of power-from-shore, increases abatement costs to 2790 NOK/tonne $CO_2$.
  - An offshore gas power hub with CCS is estimated to give abatement costs of 3270 NOK/tonne $CO_2$. OG21 would expect an onshore gas power hub with CCS solution to be less costly.
  - Further integration of the offshore gas power hub with floating offshore wind, increases abatement costs to 3330 NOK/tonne $CO_2$.
- The DNV estimates are very sensitive to assumptions on the various cost elements. Especially CAPEX on retrofitting of installations is highly uncertain. Even with low retrofitting costs, given all other cost elements constants, estimated abatement costs are higher than the assumed $CO_2$-tax of 2000 NOK/tonne $CO_2$. Only if more cost elements are assumed on the lower end, would abatement cost become less than 2000 NOK/tonne $CO_2$.
- The DNV estimates on LCOE for the four cases are all lower than the "do nothing"-alternative. The LCOE for this alternative is especially driven by $CO_2$-price and fuel costs in that order.
- Based on the estimates by DNV, a comparison with the estimates published by NPD and MD, as well as the categorization by Konkraft of electrification projects, OG21's take on the economics of electrification is:
  - Electrification abatement costs are typically 1000-3000 NOK/tonne $CO_2$. Many electrification projects are hence economically attractive with the announced $CO_2$-price of 2000 NOK/tonne $CO_2$ in 2030, but the industry needs to bring costs further down to mature sufficient projects to meet GHG reduction targets.
  - Offshore wind and offshore gas power with CCS are alternative electrification solutions to the traditional power-from-shore solutions. Both come with a cost disadvantage, which is expected to decrease over time in line with traditional cost learning curves. OG21 believes onshore gas power with CCS would be a more attractive solution than offshore solutions.
  - An LCOE approach adds further details to the discussion and should be included in evaluations. The "do nothing"-alternative could, when including $CO_2$-price and fuel costs, appear less attractive as compared to a pure abatement cost approach.

| | 0: Do nothing | 1: Power from shore (coordinated approach) | 1.1: Floating wind turbines and power from shore | 2. Gas-fired power hub offshore with CCS | 2.1: Floating wind turbines and gas-fired power hub offshore with CCS |
|---|---|---|---|---|---|
| Conceptual illustration |  | | | | |
| Short description | Running traditional gas-fired turbines without modifications. | 250 MW HVDC cable from shore with dedicated jacket for DC equipment, AC supply to platforms. | Same as case 1 including floating wind turbines with installed capacity of 85 MW. | Sevan floater 250 MW power hub as stand-alone solution located with AC supply to platforms. | Same as case 2 including floating wind turbines with installed capacity of 85 MW. |
| **Power purchased from shore** [TWh/yr] | - | 1.10 | 0.75 | - | - |
| **Power produced offshore** [TWh/yr] | 1.10 | - | 0.35 | 1.10 | 1.10 |
| **Fuel consumption** [TWh/yr] | 3.65 | - | - | 2.00 | 1.40 |
| **$CO_2$ emitted** [tonne/yr] | 722,700 | - | - | 39,400 | 27,100 |
| **CAPEX** [MNOK] | N/A | 12,780 | 15,580 | 16,760 | 19,560 |
| **O&M costs** [MNOK/yr] | 80 | 120 | 155 | 80 | 110 |
| **$CO_2$ tax** [MNOK/yr] | 1,455 | - | 0 | 80 | 55 |
| **Fuel/electricity cost** [MNOK/yr] | 790 | 580 | 400 | 430 | 300 |
| **Abatement cost** [NOK/ tonne $CO_2$ abated] | **N/A** | **2,680** | **2,786** | **3,271** | **3,326** |
| **LCOE** [NOK/kWh] | **2.41** | **1.77** | **1.84** | **2.04** | **2.11** |

*The required downtime for retrofitting is highly project specific. Electrification of assets can be completed within normal maintenance stops, depending on the technical basis and careful planning. In other cases, additional downtime will be required.

DNV

# 4. Reducing Scope 3 emissions creates opportunities

# 4 Solutions for reducing GHG emissions from the use of petroleum create value for enterprises and the society

- OG21 shares the views expressed by DNV in their report, see excerpt to the right.
- Reducing Scope 3 emissions is important for several reasons:
  - Maintain society's support for petroleum activities.
  - Maintain attractiveness for investors who increasingly weigh in climate risk in their portfolios.
  - Attract and retain talent.
  - Secure future market when the market for natural gas delivered in the traditional way, decreases.
  - Spur innovation and create new value-creating industries for Norway.
- Gas power with CCS represents an opportunity both for reducing Scope 1 emissions (see Section 3.3.3 ) and Scope 3 emissions. A well-function CCS value chain is the key uncertainty, which is being addressed through the Longship / Northern Light project. Whether the power plant should be placed in Norway or abroad at the receiving end of the gas pipelines, is a commercial as well as industry strategy decision. Factors such as the escalating geopolitical tension, the establishment of a CCS value chain in Norway, and the prospect of stimulating industry development in Norway, all pull in the direction of placing the plant in Norway.
- Blue hydrogen is less mature and will take longer time to develop. Producing blue hydrogen is cost and energy intensive. Hence, for the next few years when energy scarcity will be the main concern for Europe, blue hydrogen seems less attractive as compared to how it seemed just a year ago. The energy transition and need for decarbonization of also hard-to-abate sectors, combined with the fact that the use of low-emission hydrogen in new sectors is immature, suggest that Norway needs to keep up efforts to establish safe, secure and cost-efficient low-emission hydrogen value chains.

Excerpt from DNV report (DNV, 2022)

- **Scope 3 reporting pressures ramping up:** Oil and gas companies increasingly are expected to report on scope 3 emissions and include them in decarbonisation targets, to capture full value chain emissions. Scope 3 emissions can be defined as being the "result of activities from assets not owned or controlled by the reporting organization, but that the organization indirectly impacts in its value chain", according to the GHG Protocol. The EU Corporate Sustainability Reporting Directive will require reporting and tracking of scope 3 emissions, while stakeholders ranging from investors to NGOs expect companies to report on scope 3 emissions and develop strategies on how to reduce them.
- **Safeguarding value and competitiveness:** Devising ways to reduce scope 3 emissions for Norwegian O&G companies will become a key to the long-term competitiveness and value of the sector. Scope 3 emissions can be reduced by i.e., setting supplier requirements, decarbonising fuels upstream or downstream decarbonisation (i.e., converting natural gas to blue hydrogen or generating natural gas-fired power with CCS). Ensuring the long-term value of Norwegian O&G companies will thus likely depend on sufficiently ambitious scope 3 emission reduction targets and the credibility of strategies.
- **Tackling use of sold products emissions is key to reducing scope 3 footprint:** Around 75% of scope 3 emissions from the O&G sector stem from emissions from the use of sold products (category 11 in the GHG Protocol). This is also where investors assess the main transition risk of their oil and gas company exposure to lie, and as they look to reduce such risks, working with the decarbonisation of fuels and their use is a key element for the O&G sector to retain competitive financing over time. The focus is on natural gas, as most of the reduction from use of oil will come from a reduced demand due to alternatives (such as electrification of transport).
- **Scope 3 should also be a concern for Norway:** Nation-states have shown little appetite to take responsibility for scope 3 emissions to date, but as international carbon budgets dwindle fast pressures could increase. In Norway's case, national scope 3 emissions associated with the use of exported fossil feedstock and fuels are substantial. As pressures ramp up for corporates to take more value chain emissions responsibility, the pressure on Norway as an exporter of emissions may increase accordingly. By decarbonizing fossil fuels upstream (in Norway) or supplying CCS equipment and expertise downstream (internationally) Norway will take more responsibility for reducing exported emissions and be on the right side of this narrative.
- **REPower EU and scope 3 emissions:** Norway will be a key provider of natural gas to the EU and aiding the diversification away from Russian gas. This reduces the near-to-mid term attractiveness of exporting decarbonized natural gas in the form of blue hydrogen to Europe, as the energy losses in its conversion and reduced energy shipped (by pipeline) are negative energy security factors. This bolsters the argument for decarbonizing the natural gas downstream instead. However, over time, there is a risk that energy efficiency gains in Europe also eats into Norwegian gas exports, while low-carbon hydrogen demand in the region grows. A one-sided focus on exporting natural gas may lead to Norway not moving early enough to establish competitive hydrogen value chains. Further, this may ultimately also lead to Norway being less in control of the scope 3 emission reduction narrative.
- **Natural gas power with CCS – Maximizing gas energy security impact:** Gas power with CCS could contribute substantially to reduce scope 3 emissions from Norwegian gas, either through deployment within or outside Norway. Within Norway, the main benefits would be the scope 1 emission reductions for oil and gas operators, an increased ownership for Norway in reducing emissions from produced natural gas, the potential for electrification of industry and NCS, combined with the creation of a CCS value chain and jobs. Outside of Norway, the main benefits are reduced losses from energy transmission – key for European energy security – as well as relatively higher near-term export revenue from maximizing gas exports. Outside of Norway, positioning Norwegian companies to take part in a European CCS value chain will be key to maximizing the value for Norway and the O&G sector and documenting ownership of scope 3 GHG emission reduction efforts.
- **Blue hydrogen and hydrogen derivatives – setting the stage for new industry:** Blue hydrogen and hydrogen derivatives would create value by decarbonizing fuel/feedstock upstream – enabling Norway to take firm ownership of scope 3 decarbonization efforts and would support the establishment of new hydrogen and CCS industry. That said, energy losses from conversion and transmission would negatively impact the amount of energy shipped to Europe, which could negatively impact energy security imperatives in the near-to-medium term.



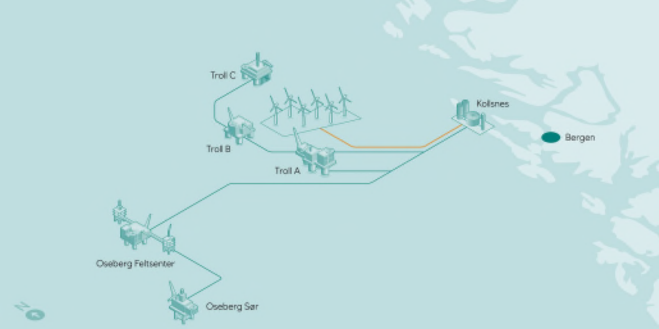
OG21

# 5. Conclusions & recommendations

# Conclusions – Electrification is crucial to reduce NCS emissions. Electrification with wind power and gas power with CCS should have a more significant role.

- The near-term GHG emission target of 50% reduction by 2030 compared to the 2005-level is achievable. Four types of technologies are especially important to meet the target:
  1. **Electrification from shore** is crucial to meet the 2030 GHG emission target for the petroleum industry. It is important that the electrification is done as efficiently as possible and with flexibility for future integration with the bigger energy system. The industry has already successfully established area solutions with collaboration between production licenses. Such collaboration will be important going forward. Cables and distribution hubs should be designed to allow for integration with offshore wind and/or low-emission gas power, and for exchanging power in both directions with the onshore grid.
  2. **Electrification with offshore wind** could be developed faster and have significant contributions to GHG reductions by 2030. Offshore wind projects isolated from the onshore grid and serving a few installations (e.g. Hywind Tampen) are important for technology scaling and experience gathering. However, since back-up gas turbines are needed for periods with little wind, the GHG emission reductions are smaller than for offshore wind integrated with larger grid systems. An offshore wind farm integrated with the onshore grid, could feed several offshore installations as well as the onshore grid with renewable energy.
  3. **Electrification with low-emission gas power hubs** could be developed faster and have significant contributions to GHG reductions by 2030. Low-emission gas power hubs, which are gas power plants with CCS, could be placed either offshore or onshore. Several offshore concepts exist on the drawing board, utilizing mostly mature technology elements, whereas the onshore solution would be conventional combined-cycle gas turbine plants combined with CCS. Costs are expected to be lower for onshore concepts.
  4. **Energy efficiency** continues to be a priority for the industry spanning all technical disciplines. With the close connection between energy use and GHG emissions, all opportunities for saving energy must be examined. Water management is an area of particular interest – a lot of energy is used to pump water from the well to the topside, separate water from the wellstream, and pump water back either for storing or pressure support. Measures to improve reservoir drainage with less water production, well completion to shut off water early, water separation in-well or at the sea bottom, are all examples of technologies that could reduce one of the biggest contributors to energy use and GHG emissions offshore.
- Abatement costs for electrification projects are typically 1000-3000 NOK/ tonne $CO_2$ as compared to a CO2-price of 2000 NOK/tonne $CO_2$ expected in 2030. Many electrification projects are as such profitable, but the industry needs to bring costs further down to mature sufficient projects to meet the 2030 GHG reduction target. Both offshore floating wind and gas power with CCS are currently more expensive electrification alternatives than power from shore, but costs are expected to decrease over time in line with traditional cost learning curves.
- The threat situation for Norwegian energy infrastructure has increased. This calls for a heightened preparedness level and increased efforts to identify and manage sabotage risks.
- Reducing Scope 3 emissions is important to maintain society's support for petroleum activities, maintain attractiveness for investors who increasingly weigh in climate risk in their portfolios, attract and retain talent, secure the future market for natural gas, and create new valuable industries for Norway. Norway therefore needs to continue R&D&I efforts to establish value chains for CCS and blue hydrogen.

The Trollvind concept (ref.Equinor)




The "Blå strøm" concept (ref.blåstrøm.no

# Recommendations

**#1 –Electrification from shore is crucial to meet the 2030 GHG emission target for the petroleum industry.**

- Power-from-shore is key to reach both the national and the industry's 2030 GHG targets. This message must be reiterated regularly.
- Electrification needs to be done as efficiently as possible and with flexibility for future integration with the bigger energy system. New radial connections should allow for integration in an offshore grid at a later stage.
- Cables and substations should be designed to allow for integration with offshore wind and/or low-emission gas power, and for exchanging power with the onshore grid.
- The industry should continue to seek area solutions and collaboration between production licenses. A coordinated approach on power from shore, low-emission gas power hubs, and offshore wind farms, can lay the foundation for a future meshed offshore grid. This will increase the redundancy and be part of a basis for development of new ocean industries.

**#2 –Electrification with offshore wind and offshore or onshore low-emission gas power hubs should be developed faster to provide significant contributions to GHG reductions by 2030.**

- Robust frameworks for offshore wind development and clarity in the basis for competition need to be in place to provide long-term investment signals and stimulate deployment.
- Clarity is needed in tax regimes for cross-over license areas between new industry (such as offshore wind or low-emission gas power hubs) and O&G assets, and how connections to the grid would impact this.
- The 30 GW target for offshore wind is an important first step. The target should be supported by a licensing and development roadmap.
- OG21 supports the measures suggested by Konkraft:
  - Contracts for difference; establish $CO_2$-fund; continue NOx-fund.
  - Norwegian authorities taking an active role in EU's work with development of frameworks for hybrid projects and the future masked offshore grid in the North Sea.

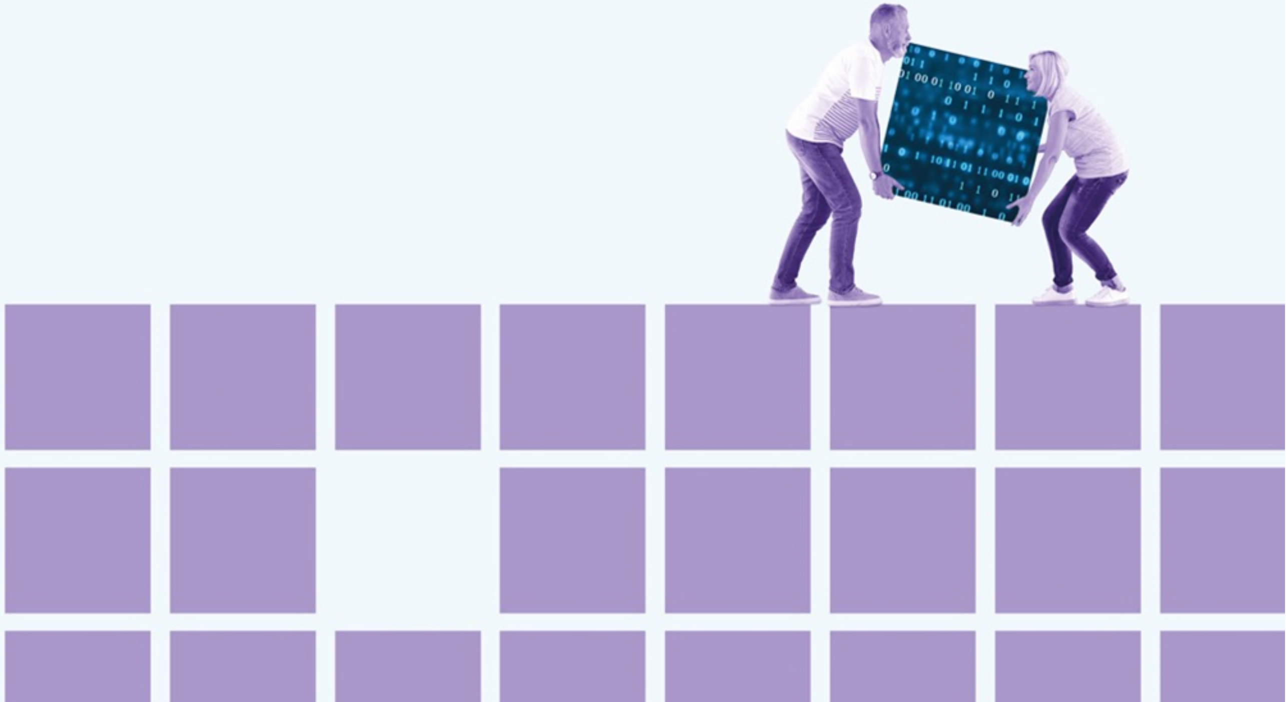
**#3 –Energy efficiency continues to be a top priority.**

- Energy is a scarce resource and must be used wisely. The industry has over many years identified and implemented measures to conserve or reduce energy use. Such efforts must continue as offshore petroleum installations increasingly become integrated with the onshore power grid through electrification.
- Energy efficiency is a big bucket of measures where the cumulative contribution of all make a big total difference. The approach therefore needs to be holistic.
- Within the holistic approach, the big energy consumers need specific attention. Water management from the reservoir to topside is a major opportunity for reducing energy use, including:
  - Improved subsurface understanding and technology to place wells better and drain reservoirs with less energy use.
  - Smart well completion to stop water inflow.
  - Water treatment at low elevation to avoid lifting of water to topside, e.g downhole or seabed separation and re-injection.
  - Optimal use of topside water separation and re-injection equipment.

**#4 – No time for complacency, industry and regulators must act now:**

- It is time-critical to mature sufficient GHG emission reduction projects to deliver on the 2030 target. Permitting, equipment delivery, and project execution all take time. The industry needs to rapidly identify and mature more projects through the feasibility and concept stages to reduce uncertainty on whether the 2030-targets will be met.
- Regulators should look at ways to speed up decision processes for licensing and permitting of GHG emission reduction projects.
- New $CO_2$ storage sites should be developed in parallel, and more license areas should be allocated. OG21 supports Konkraft's suggestion for establishing concrete targets for how much $CO_2$ should be stored on the NCS.
- The close monitoring and reporting of progress managed by Konkraft is important. If progress is not satisfactory, industry needs to react fast and implement more emission reduction measures to avoid increased $CO_2$-tax or other regulatory actions.
- Norway should increase its ambitions on development and implementation of clean technologies to position Norwegian industry and ensure a competitive advantage.
- Innovation can reduce cost and speed up the transition. R&D programs such as Petromaks2. Demo2000, Climit and Petrocenters should be strengthened.
- Long-term decarbonization must not be forgotten while striving to meet 2030 targets. R&D&I efforts on low-carbon energy carriers such as offshore wind, hydrogen and hydrogen-derived fuels, must continue.

# 6. References & abbreviations



# References


Birol, D. F. (2022, July 18). Coordinated actions across Europe are essential to prevent a major gas crunch: Here are 5 immediate measures. Hentet fra IEA: https://www.iea.org/commentaries/coordinated-actions-across-europe-are-essential-to-prevent-a-major-gas-crunch-here-are-5-immediate-measures

E24 (2022). Nytt hopp i gassprisen. 22.august 2022. https://e24.no/olje-og-energi/i/wOMmOd/nytt-hopp-i-gassprisen

Energi og klima (22.05.22), based on released note from the European Commission.

IEA. (2022). IEA World Energy Investment 2022. IEA. Hentet fra https://iea.blob.core.windows.net/assets/b0beda65-8a1d-46ae-87a2-f95947ec2714/WorldEnergyInvestment2022.pdf

IEF. (2021). Deepening Underinvestment in Hydrocarbons Raises Spectre of Continued Price Shocks and Volatility. International Energy Forum. Hentet fra International Energy Forum: https://www.ief.org/investment-report-2021

Konkraft (2022). The energy industry of tomorrow on the NCS. Climate Stretagy towards 2030 and 2050. Status report 2022. https://konkraft.no/contentassets/076be191143241858b27655fb11ad295/eng_klimarapport-ver020822-v2.pdf

Miljødirektoratet (2022). Grønn omstilling: Klimatiltaksanalyse for petroleum, industry og energiforsyning. https://www.miljodirektoratet.no/publikasjoner/2022/september/gronn-omstilling-klimatiltaksanalyse

Meld.St.36 (2020-2021). Energi til arbeid – langsiktig verdiskaping fra norske energiressurser. https://www.regjeringen.no/contentassets/3d9930739f9b42f2a3e65adadb53c1f4/no/pdfs/stm202020210036000dddpdfs.pdf

NPD (2020). Kraft fra land til norsk sokkel. https://www.npd.no/fakta/publikasjoner/rapporter/rapportarkiv/kraft-fra-land-til-norsk-sokkel/

NPD (2022). Resource report 2022. https://www.npd.no/globalassets/1-npd/publikasjoner/rapporter/ressursrapporter/2022/en/resource-report-2022.pdf

Rystad Energy (2019). Technologies to improve NCS competitiveness. https://www.og21.no/contentassets/e1765573b1044740ae5425fc27e80dab/technologies-to-improve-ncs-competitiveness_rystad-energy_final.pdf

# Abbreviations

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|---|---|
| bcm | Billion cubic meter |
| CAPEX | Capital expenditures |
| CCS | Carbon capture and storage |
| EOR | Enhanced oil recovery |
| GHG | Greenhouse gas |
| IPCC | International Panel on Climate Change |
| LCOE | Levelized cost of electricity |
| LNG | Liquified natural gas |
| MD | Miljødirektoratet |
| MPE | Ministry of Petroleum and Energy |
| NCS | Norwegian continental shelf |
| NOC | National oil companies |
| NPD | Norwegian Petroleum Directorate |
| O&M | Operations and maintenance |
| R&D&I | Research, development and innovation |

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