The Hague Centre
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The European tank storage sector
and the global energy landscape

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HCSS Geo-economics

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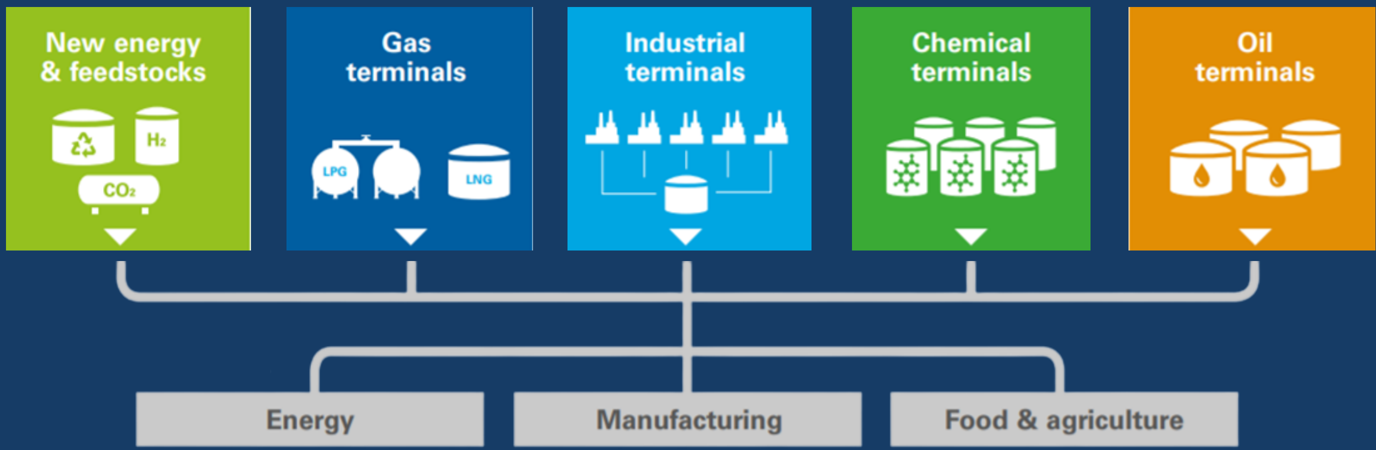
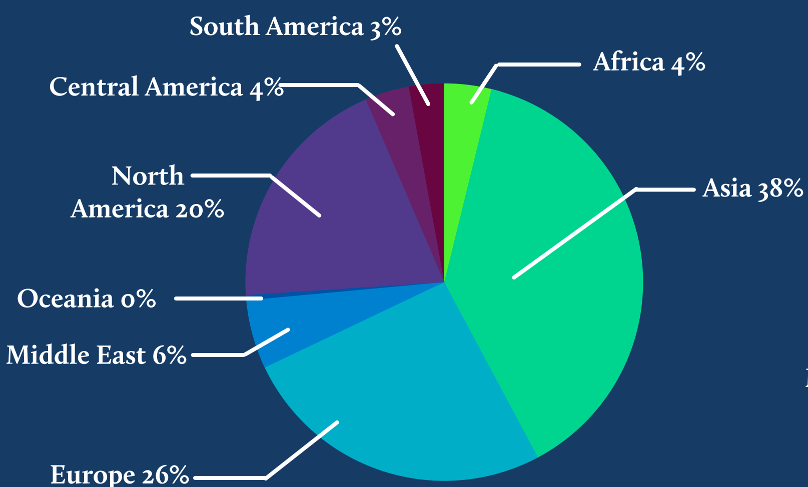
The European Tank Storage Sector

The role of independent storage in global supply chains:



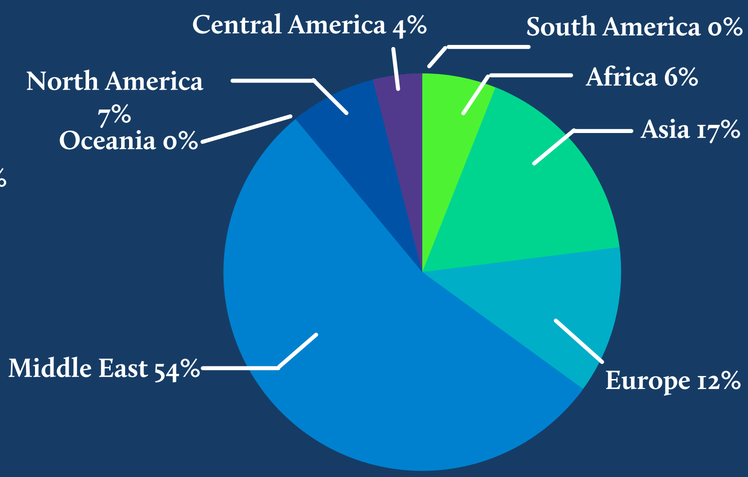
Source: Vopak (2020)

Market share tank storage capacity by region:



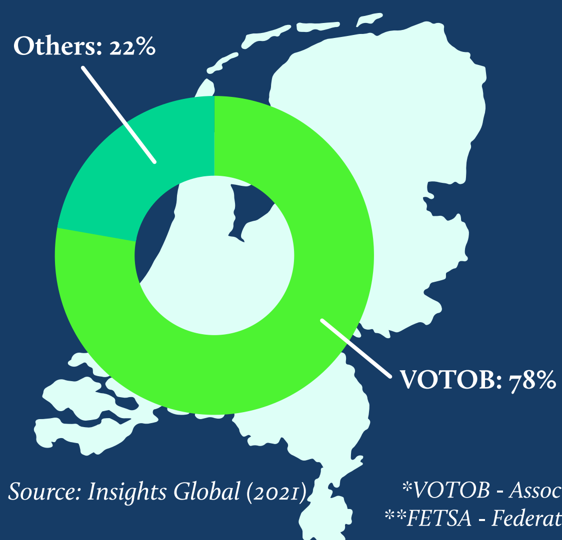
Source: Insights Global (2020)

Terminals under construction by region



Source: Insights Global (2020)

Share VOTOB* tank storage capacity Netherlands:



Source: Insights Global (2021)

European independent tank storage sector (FETSA):

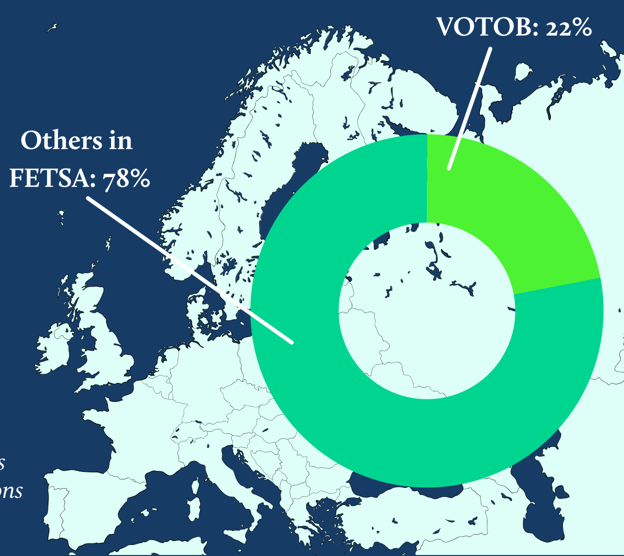
19 000 employees

€5 billion in future investments

Source: FETSA (2019)

Share VOTOB tank storage capacity FETSA**:

Source: FETSA (2019)



**VOTOB - Association of Dutch Tank Storage Companies*
***FETSA - Federation of European Tank Storage Associations*

Contents

1. Introduction

The Dutch Association of Tank Storage Companies (VOTOB) is engaging in a broad set of activities to strengthen its strategic capacity. This capacity (to strengthen knowledge, orientation and anticipation capabilities) is influenced by macroeconomic and geopolitical changes resulting from the energy transition. International value chains of fuels and chemicals will be transformed by the global energy transition and decarbonization policies. Emerging realities and accompanying innovations will require the storage sector to constantly adapt. Designing a successful response to these changes involves a long-term strategy aimed at preserving the sector's profitability and the license to operate. VOTOB's position can be improved by enhancing the sector's visibility on national and local political levels, as well as by reestablishing the awareness of its importance for the Dutch and international economy.

This paper supports VOTOB's objective by providing a better understanding of how the rapidly changing global context will impact the (European) tank storage sector and draws some first conclusions for the way forward.

2. **Background and rationale**

In the Netherlands, VOTOB represents the independent storage companies, which together have a capacity of approximately 25.5 million m^3.[1] This is a large number, representing about 78 % of the country's total storage capacity.[2] Apart from VOTOB, energy companies themselves can manage dependent storage, thus contributing to the total national capacity.

Within Europe, as a consortium partner of FETSA (Federation of European Tank Storage Associations), VOTOB is one of the biggest independent liquid storage associations. The total capacity of FETSA is 120 million m^3, of which VOTOB's members hold about 22 %.[3] VOTOB is a key player in the Dutch and North-Western European industrial clusters, thus representing an important sector of both the Netherlands' and European economies. The European tank storage sector employs 19 000 people and in the next five years will facilitate investments of more than 5 billion euros.[4]

Despite the importance of the tank storage sector in Dutch and European economies, the next years will pose significant challenges to the sector. The main priority of the EU for the following decades is to transition away from fossil fuels, in accordance with the European Green Deal.[5] Low-carbon hydrogen, strongly supported by the Green Deal and the Dutch Climate Agreement ('Klimaatakkoord') could be deployed on a large scale.[6] Innovations for electricity ('electrons'), e-fuels and hydrogen storage are expected to develop in the next 10 to 15 years and create significant opportunities for the international economy and possibly for the tank storage sector. Although the European economy will rapidly transform its energy mix, oil and (natural) gas ('molecules') will remain important. At the moment, legislation preventing further investments in oil and gas and regulating oil investment reporting, is causing financial pressure for the tank storage sector. The energy transition is complicated by broader geopolitical developments caused, among others, by EU's digital transformation and strategic autonomy goals, by the changing role of fossil fuel supplier countries, by the spatial shift of industrial clusters away from Europe and into Asia, and by China's control over entire supply chains for green technologies.

The challenges inflicted on the tank storage sector by the dynamic changes within the global context will be substantial. This paper analyses the geopolitical and macro-economic dimensions of the energy transformation, which are crucially important for the future of the sector.

1 FETSA, "Tank Terminals in Europe - Key Figures," 2018, 6.

2 Insights Global, 2021.

3 FETSA, "Tank Terminals in Europe - Key Figures," 2019.

4 FETSA.

5 European Commission, "A European Green Deal," Text, Priotities 2019-2024 - European Commission, 2020, https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en.

6 Ministerie van Economische Zaken en Klimaat, "Klimaatakkoord" (Den Haag, June 28, 2019), https://www.klimaatakkoord.nl/documenten/publicaties/2019/06/28/national-climate-agreement-the-netherlands.

3. **The tank storage sector**

The tank storage sector is an integral part of a complex web of global activities, including extraction of raw materials, production, refining, trade, investment and consumption. These are highly intertwined and mutually interdependent. Changes in one stage of the supply chain impact the entire system. Figure 1 illustrates the role of independent storage companies within supply chains of oil, gas and chemicals, the three main categories of products handled by the tank storage sector.

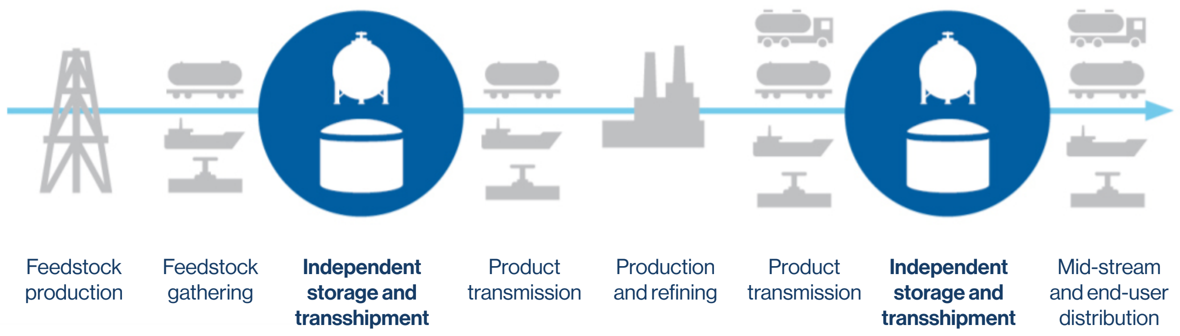


Figure 1: The role of independent storage in global supply chains. Source: Vopak.[7]

Fossil fuels, particularly oil and gas products, remain the backbone of the world's energy mix for the years to come. Despite ambitious global plans to transition toward a renewable energy system, fossil fuels are expected to remain key in energy generation until at least 2030. Oil can be traded as crude or in one of the three categories of refined products – low-flashpoint, including naphtha and gasoline; middle distillates, including gasoil, jet-kerosene and diesel; as well as fuel oil. Secondly, natural gas can be stored in liquefied or gaseous form. Chemicals such as methanol and xylene, as well as vegetable oil and biofuels, are also stored in tanks.

7 Vopak, "Roadshow Presentation Q1, 2018" https://www.vopak.com/system/files/vopak_q1_2018_roadshow_presentation_1_0.pdf.

The US, Russia and Saudi Arabia, through their private and state-owned companies, have been the largest global crude oil exporters for the last decades.[8] More than half of the global natural gas is produced in a handful of countries, including the US, Russia, Iran, China and Canada.[9] Oil and gas are primary products in the petrochemical industry, the latter accounting for approximately 13 % of global oil demand.[10] While oil demand for the transport and construction sectors is expected to decrease until 2030 to about 5-10% of total demand, the petrochemical industry will become more dependent on oil. It is expected to account for approximately 16 % of global oil demand.[11]

Bulk liquids are generally consumed in four main industries – energy, manufacturing, food & agriculture, and transport (aviation, marine and road). Apart from these industries, governments also purchase oil and gas in order to complete their strategic stocks.

The role of tank storage is essential in ensuring the efficient functioning of global markets. Three main functions are assumed by the tank storage sector – logistic, trade platform and strategic storage. First, it carries an important logistic role in distribution networks and in its integration with industrial complexes. Second, tank terminals are vital components of international trade markets, increasingly functioning as buffers for potential supply disruptions. Traders use storage units as instruments for the optimization of profits.

The international commodity market is a key driving force of the global economy. Commodity traders of raw materials, including fuels, chemicals and foods, have been central to some of the key economic events of the last 50 years. Local and international traders are strongly intertwined with tank terminals, the latter being key in absorbing market shocks, reducing price volatility and providing stability. The largest commodity trading companies include Vitol, Glencore, Cargill and Trafigura, who in 2019 had a combined turnover of $725 billion.[12] Energy companies are also partaking in trade. Although not officially disclosing traded volumes, Shell trades more than Vitol or Trafigura.[13]

Tank storage is not only vital for private actors involved in commodity trading – it is also highly important for governments to hold strategic stocks. Many strategic terminals are designated as *critical infrastructure* by the EU and national governments due to their importance in providing uninterrupted supplies of energy to industrial, transport and defense markets. This is particularly the case with petroleum products and natural gas, which are necessary for ensuring energy security of supply. The COVID-19 pandemic highlighted the importance of strategic national stocks in case of disruptions in global supply chains. Tank storage plays a pivotal role in securing the continued functioning of socio-economic processes in times of both stability and crisis.

8 US Energy Information Administration, "Oil and Petroleum Products," EIA, October 26, 2020, https://www.eia.gov/energyexplained/oil-and-petroleum-products/where-our-oil-comes-from.php.

9 IEA, "Natural Gas," IEA Atlas of Energy, 2020, http://energyatlas.iea.org/#!/tellmap/-1165808390.

10 IEA, "Oil Demand in the Petrochemicals, Industry and Buildings Sectors in the Stated Policies Scenario, 2019-2030," IEA, October 12, 2020, https://www.iea.org/data-and-statistics/charts/oil-demand-in-the-petrochemicals-industry-and-buildings-sectors-in-the-stated-policies-scenario-2019-2030.

11 IEA.

12 Javier Blas and Jack Farchy, *The World For Sale: Money, Power, and the Traders Who Barter the Earth's Resources* (Oxford University Press, 2021), 18.

13 "Shell's Oil Trading Profit Doubled in 2020," Tank Terminals, March 15, 2021, https://tankterminals.com/news/shells-oil-trading-profit-doubled-in-2020/.

Table 1: Tank storage capacity per region and per terminal, 2020. Source: Insights Global

Geographical region	Capacity (kcbm)	Market share	Number of tanks/ terminals	Average capacity/ terminal (bcm)
Africa	37,264	4 %	13	152
Asia	374,325	38 %	26	353
Europe	251,145	26 %	27	215
Middle East	54,743	6 %	21	412
Oceania	4,032	0 %	20	60
North America	191,182	20 %	19	131
Central America	35,077	4 %	20	171
South America	27,857	3 %	15	81

The three regions with the most storage capacity are Asia, Europe and North America, as illustrated by Table 1. Particularly in relative terms to its population size, Europe controls a very significant market share of all storage (26 %). At the same time, Europe has the highest number of tanks per terminal in the world, although it falls behind the Middle East and Asia in terms of average capacity per terminal. Due to the international and private character of tank storage companies, however, ownership and location of the terminals do not necessarily coincide. For example, despite Vopak's Dutch origins, the company owns much more storage terminals in Asia and the Middle East than it does in Europe.

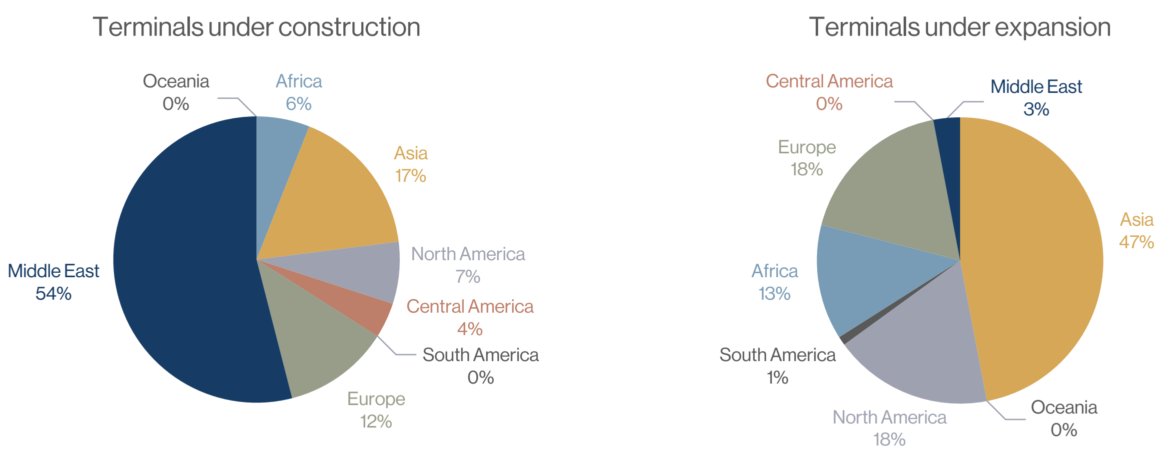


Figure 2: Terminals under construction and under expansion, 2020. Source: Insights Global

When it comes to storage capacity under construction, the Middle East dominates the world-wide ranking with 54 % of the total (see Figure 2). Asia and Europe place themselves on the second and third position, respectively. Asian countries – specifically China – are by far under-taking the largest terminal expansion in the world, the region taking up almost half of the world's total expansion. North America and Europe, followed by Africa, are also considerably expanding their storage capacity.

4. Global context

Geopolitical and economic relations of interdependence are becoming increasingly and inextricably connected to the forces of change of the global energy transition. The transition toward a renewable energy system will change the global power balance, the architecture of economies and the types of commodities that will be essential for socio-economic functions.

For a long time, the world has hesitated to tackle the problem of climate change. The Paris Agreement in 2015 was a turning point, after which many countries started to take measures to combat climate change in earnest. Within the Netherlands there is widespread agreement to contribute to a worldwide effort to limit global warming to a level well below 2 degrees towards 2100.

Limiting global warming implies reducing greenhouse gas emissions and transitioning to a new, net zero-carbon energy system. This requires a drastic reduction of the use of fossil fuels and therefore a shift in the role of tank storage. Technological breakthroughs, cost reductions for existing techniques, political choices and acceptance by society will shape the new energy system and the position of the storage sector within the energy transition. Many things are still unclear, but the contours of the new system are starting to emerge. This section discusses some of the main trends that will affect the tank storage business in the decades to come – the developments in oil and gas markets, electrification, hydrogen and biofuels.

4.1. Oil

In the 1970s it was widely feared that commodities were being depleted at a rapid rate and that the 21st century would be characterised by severe shortages, in particular for an essential commodity like oil. At the time, global proved oil reserves were estimated to be about 650 billion barrels.

Fifty years later, global proved oil reserves stand at over 1700 billion barrels. Technological progress ensured that reserves have risen at a much faster rate than that of reserve depletion due to oil production. Running out of oil reserves is, at least on a global basis, no longer a concern. The problem is the opposite. There is so much oil that is attractive to consume, representing a large amount of energy which can be transported easily and produced cheaply, that we are running into a constraint of a completely different nature: consuming all this oil (and coal, natural gas) will result in a temperature rise that is completely unacceptable.

Over the years following the Paris Agreement, estimates of future oil demand have been revised downwards as countries have, in general, become more determined to tackle climate change. Oil and gas are no longer seen as commodities that will be used for an indeterminate amount of time. For oil companies, this implies a gradual transfer to a new business model (assuming that they will not choose the option of becoming part of a sunset industry).[14] Industry sectors like aviation and shipping will need to reduce emissions and eventually find a way to function without emitting major amounts of greenhouse gases.

For tank storage, this implies a shift from fossil fuels to energy carriers like hydrogen, which do not emit greenhouse gases when used. In the following years, the tank storage sector will need to balance the slowly decreasing demand for oil, with the increasing demand of low-carbon energy sources. This is both a challenge and an opportunity. The transition will require a costly reconfiguration, but it could allow tank storage to have an active role in the new energy system.

An increasing dependence on OPEC+

IOCs (International Oil Companies, like ExxonMobil, BP and Shell) are reducing their investments in new oil and gas fields. Since 2014, their upstream investments have decreased by about 50%. Break-even costs, payback periods and carbon footprint determine the destination of these reduced investments. For deep-water, Brazil, Guyana and the Gulf of Mexico are the very best areas. They offer the best mix of costs, taxation, geology and local content regulations. US shale oil remains attractive due to its extremely short payback time and the flexibility with which investments can be made here. Investments in new oil sands projects (medium break-even costs, long payback times and a high carbon footprint) have come to a virtual standstill. Oil production of the IOCs is expected to gradually decrease.

Several NOCs (National Oil Companies) in countries like Saudi Arabia or the United Arab Emirates (UAE) have, on the other hand, announced plans to increase production capacity. Over the last decade, Russia doubled its upstream investments, and its recent 2035 oil and gas strategy aims to stabilise oil production and increase gas production by about 30%.[15] Countries like Saudi Arabia and Russia have so far not abandoned their current business model, producing fossil fuels.

These developments imply that the market share of OPEC+ (OPEC plus partners, out of which Russia is by far the most important one) is likely to increase during the coming decades of the energy transition. This is in particular the case for low-cost oil producers that have plentiful reserves, such as Saudi Arabia and Iraq. The European Union (EU), in contrast, is now approaching a phase where it is still heavily reliant on oil and gas but is hardly producing them anymore.

14 DNV GL, "New Directions, Complex Choices: The Outlook for the Oil and Gas Industry in 2020," 2020, https://brandcentral.dnvgl.com/fr/gallery/10651/others/4f3e1127a113440b8cef2ea87e273b9a/4f3e1127a113440b8cef2ea87e273b9a_low.pdf.

15 Tatiana Mitrova and Vitaly Yermakov, "Russia's Energy Strategy-2035: Struggling to Remain Relevant," Russie.NEI.Reports (Ifri, December 10, 2019), https://www.ifri.org/en/publications/etudes-de-lifri/russieneireports/russias-energy-strategy-2035-struggling-remain.

Lower, more volatile oil prices?

A country like Saudi Arabia, producing way below its geological potential, has a ratio between proved oil reserves and yearly production of over 60 (for the IOCs this ratio is, on average, about 10). The major Gulf producers (Saudi Arabia, Iraq, Kuwait and the UAE) now face a dilemma: continue to maximise the oil price (their policy so far) or minimise the amount of oil that will be left in the ground. As a result, it may become more difficult to keep the cohesion within OPEC+. This would lead to a downward pressure on oil prices.

It is by no means a given, but a realistic scenario, that oil prices will tend to be structurally low as the end of the oil era approaches and that oil production will gradually be shifting to a more limited number of low-cost producers. A prolonged period of low oil prices could result in more instability in the Middle East, potentially resulting in a temporary disruption of oil supply and an oil crisis. We do not pretend to be able to predict future oil markets; we merely aim to note a number of potential developments during the late phase of the oil era. This could be a shift towards lower cost oil producers, a systematic downward pressure on oil prices and increased volatility. In a world with more volatile oil prices, opportunities for more profitable trading in oil increase and securing oil storage could come at a higher premium.

Whilst oil and gas production are decreasing in most of the developed world and Asia, the US has been a notable exception. Low-cost fracking has enabled the US to become one of the three top oil producers (with Saudi Arabia and Russia). The US has become a net exporter of gas and is, on a net basis, currently self-sufficient for oil. Whilst the US is losing focus on the Middle East, China (increasingly reliant on Middle East oil) is increasing its focus here. Chinese oil companies are taking positions in Middle East oil field assets, aiming to ensure influence on the destination of oil that is produced here.

Cooperation or rivalry?

IOCs have a long tradition of making long-term scenarios for the future world and its energy system. To what extent are we moving towards a world where countries cooperate, in general and more specifically on the energy transition and combating climate change? And to what extent are we going towards a world where short-term targets and economic rivalry between countries take centre stage? This is the central question in Equinor's long term scenario studies.[16] For the latter scenario, in which climate change is not addressed adequately on a global basis, climate change could result in reaching a number of tipping points over the coming decades. These could lead to major changes of the oceanic or atmospheric circulation patterns. As a result, a rapid and disorderly exit of fossils fuels, ("delayed and disorderly" in the BP scenario studies) could be enforced upon us, rather than a more gradual and orderly scenario.

There is a tendency to expect future developments to be in line with plans (e.g., the Klimaatakkoord for the Netherlands) or Agreements (e.g., the Paris Agreement). The emphasis is on backcasting scenarios, like the IEA's sustainable development scenario, that have a desired outcome as a hard constraint.[17] The track record in meeting goals regarding combating climate change, whether on a national or global basis, has been relatively poor, however. Forecasting scenarios may run the risk of underestimating the change of a transition in times that are definitely not "business as usual". Backcasting scenarios, on the other hand, run the risk of underestimating the complexities and challenges associated with a complete transition of the energy system.

16 Equinor, "Energy Perspectives 2020: A Time of Great Uncertainty," 2020, https://www.equinor.com/en/sustainability/energy-perspectives.html.

17 IEA, "World Energy Outlook 2020" (Paris: IEA, 2020).

For companies in the energy world, under severe Environmental, Social, and Corporate Governance (ESG) pressure, this represents a dilemma. Should business strategy be solely based on desired backcasting scenarios or should they be also based on forecasting scenarios in which a desired outcome is not reached? Oil demand is expected to decrease up to 2050, but the difference between both sets of scenarios is huge (see Figure 3). As mentioned above, the expected contraction in demand has led international oil companies to decrease investments in new oil fields. However, even if the demand follows the sustainable development scenario, for a well below 2 degrees outcome, the existing oil fields will not be sufficient to meet demand. There is a large gap, illustrated in Figure 3, between expected future demand and future supply, provided that no new investments are made in oil fields.

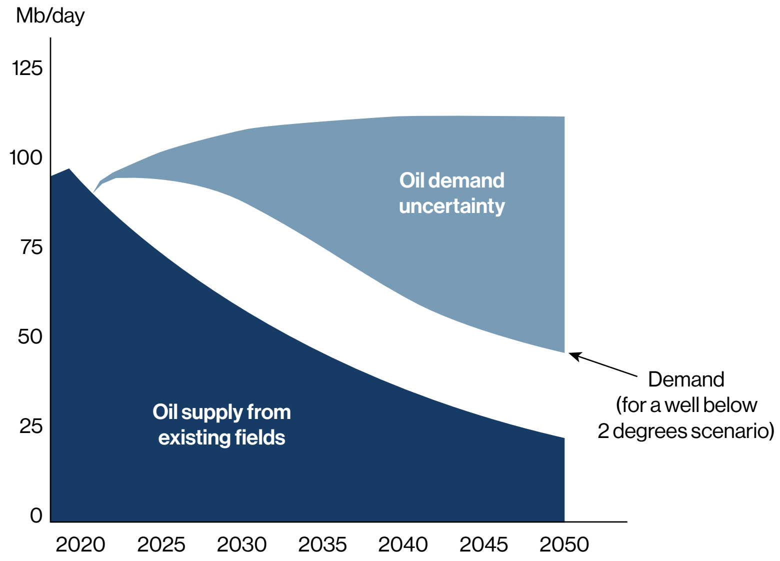


Figure 3: Long term oil supply (from existing fields) and oil demand. Source: Equinor scenarios.18

Short term oil demand uncertainty

In the short term there is also considerable uncertainty of oil demand; even for a very short time frame of 5 years, close to the time that it takes to develop a new oil field. Figure 4, based on the March 2021 IEA Oil report, illustrates the large differences between pre- and post-Covid-19 pandemic forecasts. The same figure also showcases the large differences between a base oil demand 5-year forecast and a 5-year forecast in which strong policies are implemented in order to reduce greenhouse gas emissions.[19]

The 'strong policies' case includes a number of measures and developments:

- that about 50% of the work which allows teleworking, will be done at home, on a global basis;
- that efficiencies increase faster than expected and that sport utility vehicles (SUV's) will be rapidly phased out;
- that air travel will be dramatically reduced (e.g., 50 % for business travel, structurally and on a global basis);
- that electric vehicle (EV) growth is faster than expected and that the global EV fleet grows to 100 million vehicles by 2026;
- that higher taxes on fossil fuels will be implemented more quickly.

18 Equinor, "Energy Perspectives 2020: A Time of Great Uncertainty."

19 IEA, "Oil 2021" (Paris: IEA, 2021), https://www.iea.org/reports/oil-2021.

It is worrying to note that even such strong measures are not fully sufficient to reach a less than 2 degrees warming path. Current developments suggest that governments are more inclined to ensure a post-Covid-19 economic recovery than drastically reducing greenhouse gas emissions.

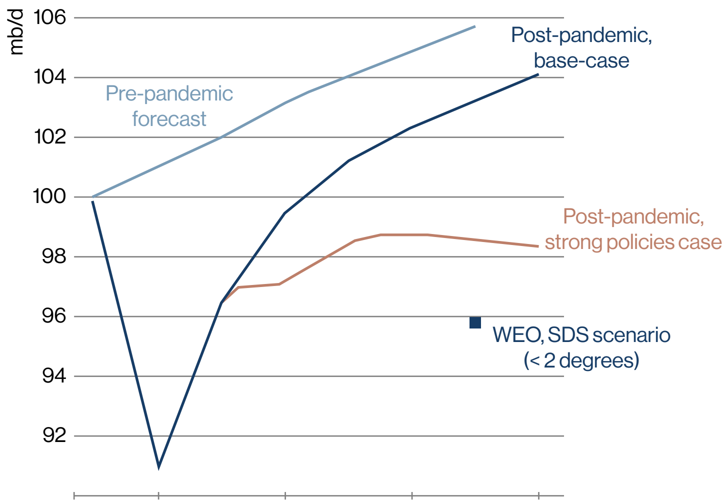


Figure 4: Short-term oil demand uncertainty (Source: IEA 2021 oil report).[20]

4.2. **Natural gas/LNG**

For natural gas, the outlook for demand is considerably better than for oil. Prior to the Covid-19 pandemic, global natural gas demand was growing by 2-4 % on a yearly basis and global liquefied natural gas (LNG) demand was growing at about twice that rate. Coal to gas switching is in full swing in the US and the EU and has only recently started in Asia.

As for oil, however, there is considerable uncertainty on future gas demand. Peak gas demand may arrive already in the 2030s but is more likely to happen in the 2040s (see Figure 5).[21] The trend towards a greater share of LNG is likely to continue. Until renewable sources can fulfil energy demand, natural gas storage is important to guarantee European energy security.

The flexibility that LNG offers becomes a greater advantage within an uncertain long-term future for fossil fuels, in which the hurdle to build new long-distance pipelines is becoming bigger.[22] The increasing role of LNG over the last decade has resulted in a convergence of natural gas prices on the three major markets (US, EU and Asia). The huge price differences over the 2010-2015 period are unlikely to be repeated. LNG has made it possible to develop remote gas fields. Low-cost shale gas from the US can now be transported to the EU and Asia, resulting in increased competition and limiting the pricing power of Gazprom in Europe. In addition, there is a move away from long term oil-indexed pricing for natural gas. The growth of LNG has been accompanied by a growth in the number of smaller capacity floating storage and regasification units (FSRU's), especially in developed countries.

20 IEA.

21 Equinor, "Energy Perspectives 2020: A Time of Great Uncertainty"; IEA, "World Energy Outlook 2020."

22 Royal Dutch Shell, "Shell LNG Outlook 2021" (Royal Dutch Shell, 2021), https://www.shell.com/energy-and-innovation/natural-gas/liquefied-natural-gas-lng/lng-outlook-2021.html.

LNG markets are, following a substantial rise in capacity over the 2014-2020 period (first in Australia, later in the US), well supplied. Following the Covid-19 pandemic, this situation is likely to continue. As for oil, we expect for LNG a gradual shift towards low-cost producers during the energy transition. Future LNG capacity additions are more likely to be in Qatar, Russia or the US than in e.g., Australia. Market leader Qatar going ahead with a major LNG expansion project during the current pandemic is an illustration of this shift towards low-cost producers.

We expect that carbon certificates for LNG deliveries (stating their scope 1 and scope 2 emissions and staying below certain agreed levels) will become commonplace. Combating methane emissions will gradually get much more attention and may become a challenge for producers with relatively high methane leakages (e.g., Russia, US shale gas).

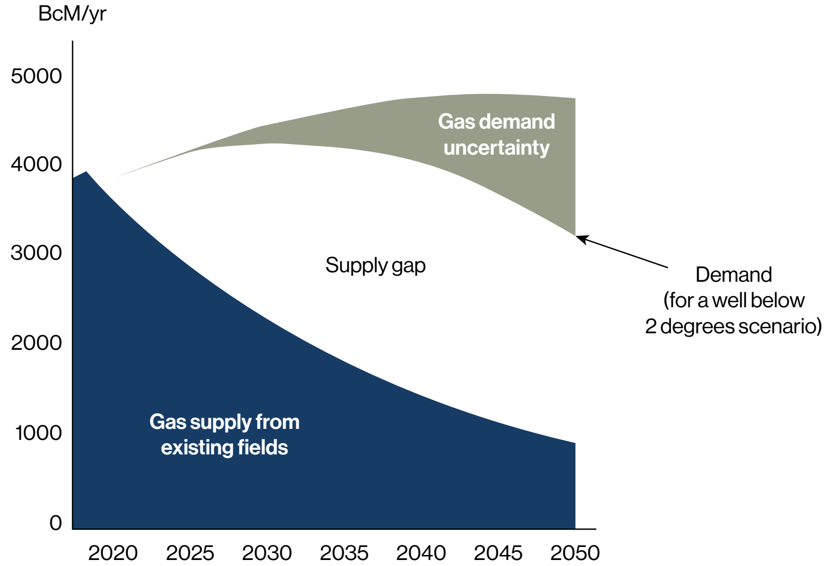


Figure 5: Long term natural gas supply (from existing fields) and demand. Source: Equinor scenarios.[23]

Like in the case of oil, there is a major gap between the expected gas demand up to 2050 and the supply from existing fields, if no additional investments were to take place. While globally (US, Russia, Qatar) new investments are being made in gas production capacity, in Europe and the Netherlands the business climate is sub-optimal. Anti-gas views in the Netherlands, combined with ambitious national and European climate plans, have led to this sub-optimal climate.

EU: an increased dependency on imported gas

Between 2012 and 2019 yearly imports of piped gas from Russia in the EU increased from about 140 to close to 200 billion cubic metres (BcM). During the same period, EU LNG yearly imports increased from about 40 to 90 BcM. In 2019 almost 40% of natural gas consumed in the EU originated from Russia. Increasing LNG supply and an ample EU LNG import capacity are currently felt to be a sufficient counterweight against the increasing dependency on Russian imports.

Over the coming decade the EU import dependency is expected to further increase as demand remains relatively stable and production continues to fall. Up to 2030, increased natural gas demand due to coal to gas switching is expected to approximately cancel decreased gas demand due to an increasing role of renewables in power generation. It is not a given that LNG markets will remain oversupplied. At some stage, especially during a relatively cold winter, the EU may have to compete on price with Asia for adequate LNG supply.

23 Equinor, “Energy Perspectives 2020: A Time of Great Uncertainty.”

Germany, phasing out both nuclear and coal, is expected to see its yearly natural gas consumption increase from current 90 BcM to about 110 BcM in 2035. Germany is the only major European country without LNG import capacity, although plans exist for 3 potential new LNG terminals. The problem for such new gas infrastructure projects is that they may be necessary, and lucrative, for a limited period only, before natural gas is eventually phased out as well.

For natural gas there is a risk that during the energy transition all attention goes toward setting up a new energy system, and that adequately maintaining the current system receives little attention. With the demise of the Groningen gas field, a combination of long-term supply contracts, sufficient LNG import capacity and sufficient gas storage capacity becomes essential. It is as yet unclear which government entity in the Netherlands will address these issues, especially after the 2022 closure of Gasterra.

4.3. **Electricity**

A key part of the energy transition will be the further electrification of the energy system. Currently, the share of electricity in the global, final energy mix is about 20%. This is expected to rise to at least 50%, and potentially much more, over the course of the energy transition. The increased electrification of society and thus importance of electricity storage is an opportunity for tank storage to reposition itself within the transition toward the new energy system.

The use of electricity does not result directly into the emission of greenhouse gases. Its carbon footprint is solely dependent on the way electricity is produced. The great enabler for the increasing role of electricity has been the rapid reduction in the cost of electricity from solar and wind over the last two decades. Even though the potential for electricity from solar and wind varies significantly, many countries have a good potential for at least one of these two sources (see Figure 6). In combination with a similar cost reduction in batteries, this makes a rapid growth of electric vehicles possible; a growth that has only just started.[24]

Full cycle greenhouse gas emissions for solar, wind, biomass, hydro, geothermal and nuclear are similarly low. Of these different sources, electricity from hydro (in mountainous areas), geothermal (volcanic areas) and biomass are difficult to scale up in the massive way that is now required. Costs for new nuclear power plants have risen substantially in the western world and, unless this cost trend is reversed, new nuclear power plants are unlikely to play a major role in North Western (NW) Europe. For countries in Asia, where the costs of new nuclear plants are structurally about a factor 2-3 lower than in the US or NW Europe, the prospects for new nuclear energy are much better.[25]

In the Netherlands wind, and in particular offshore wind, is expected to become the backbone of the new electricity system.[26] Offshore wind encounters less resistance from society. At the same time, the location of the Netherlands, adjacent to a shallow sea with relatively high wind

24 IEA, "Projected Costs of Generating Electricity 2020" (Paris: IEA, 2020), https://www.iea.org/reports/projected-costs-of-generating-electricity-2020.

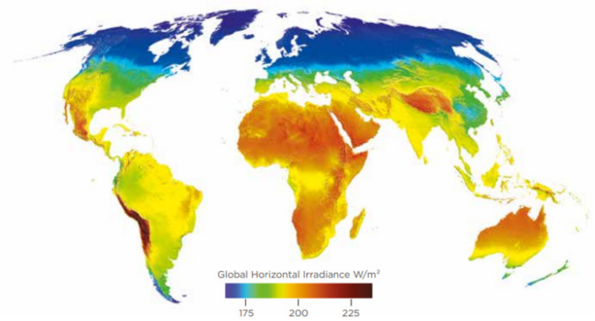
25 MIT Energy Initiative, "The Future of Nuclear Energy in a Carbon-Constrained World" (MIT, 2018), https://energy.mit.edu/research/future-nuclear-energy-carbon-constrained-world/.

26 TNO, "Scenario's Voor Klimaatneutraal Energiesysteem," TNO, accessed April 12, 2021, https://www.tno.nl/nl/aandachtsgebieden/energietransitie/roadmaps/systeemtransitie/de-sociale-aspecten-van-de-energietransitie/scenario-s-voor-klimaatneutraal-energiesysteem/.

speeds, makes offshore wind an attractive option. In 2050, according to the Climate Agreement, about 11 GW of offshore wind is aimed to be generated in the Netherlands (about 40% of current power consumption).

On a global basis, most growth in renewable electricity is expected to come from solar. Cost reductions for solar panels have systematically decreased, at a higher rate than cost reductions for wind turbines. Expectations are that this trend is set to continue. For many countries at lower latitudes, in particular where ground prices are relatively low, solar electricity is expected to be the most attractive option. As a result, the lowest production costs for green hydrogen are expected to be realised in regions like the Middle East and North Africa.[27]

For many countries, electricity from solar and wind will the pillar of the new electricity system (and to some extent for the new energy system as a whole), with natural gas as the most important additional fuel for the time being. Next to electrons, molecules will continue to play an important role as well (be it less dominant). While a future *all electric* energy system may be theoretically possible, a system analysis of future energy systems, optimising for lowest cost, looks very different. 28 It is relatively expensive to store or transport electricity. A completely electrified system is thus not the most financially advantageous option. For some applications, a high energy density of the energy carrier used is essential.



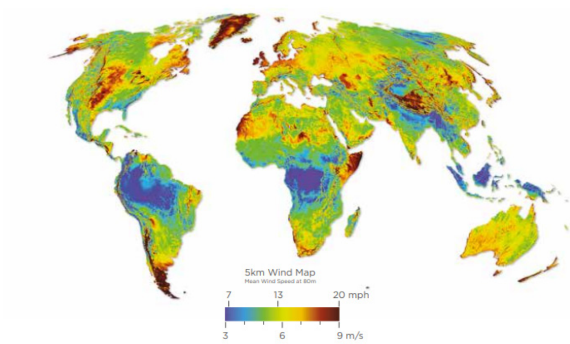


Figure 6: World solar and world wind potential. Source: Irena.[29]

For tank storage it is the reduction of market share for liquid and gaseous fuels and energy carriers that comes to the fore. It remains unclear whether, and to what extent, this reduction in market share will also lead to a reduction in absolute volumes. The world population is still growing and many billions of people in developing countries are aiming to improve their living conditions, resulting in a greater demand for energy. Still, the increased importance of electricity storage is essential for tank storage and should be accounted for in long-term strategies.

27 IRENA, "A New World: The Geopolitics of the Energy Transformation" (IRENA, January 2019), /publications/2019/Jan/A-New-World-The-Geopolitics-of-the-Energy-Transformation.

28 Tennet, "Systeemintegratie belangrijk om klimaatdoelen te halen," Tennet, February 15, 2019, https://www.tennet.eu/nl/nieuws/nieuws/systeemintegratie-belangrijk-om-klimaatdoelen-te-halen/.

29 IRENA, "A New World."

4.4. **Hydrogen**

Hydrogen is the main candidate for a complementary role to electricity in the new energy system. It is a major component of the EU Green Deal.[30] The question is not so much whether hydrogen will be part of the new energy system but how big its role will be. A few questions come to the fore:

- What will be the market share of hydrogen in the new energy system?
- Is there still a role for blue hydrogen, in addition to green hydrogen?[31]
- Will the international transport for hydrogen take off in earnest or will it be primarily produced locally?

The Netherlands has the ambition to become a hydrogen hub. Answering the above-mentioned questions will help define the role of tank storage in the newly emerging Dutch, European and global hydrogen markets.

Advantages and disadvantages

The main advantage of hydrogen is that it is a versatile energy carrier that does not emit greenhouse gases when used. Like electricity, its total full-cycle carbon footprint depends almost entirely on the way it is produced. Hydrogen can be produced without emitting CO_2 in any place where zero carbon electricity and water is available. It can be produced with low CO_2 emissions in any place where natural gas and water is available and where CO_2 can be used or injected into the subsurface. It has an energy density similar to that of fossil fuels and can be stored, or transported, at a much lower cost than electricity (but at a higher cost than fossil fuels).

There is no straightforward answer to the question whether the existing natural gas network can be used for hydrogen transport (beyond blending in a small fraction of less than 5-10 %).[32] Hydrogen can result in embrittlement of material but as long as pressures (and pressure changes) are kept within certain limits this should not be a showstopper for most existing high-pressure networks. Centrifugal compressors may need to be changed out, depending on desired capacity, for piston compressors.

Hydrogen also has many disadvantages. Green hydrogen is still very expensive. Blue hydrogen does not fully eliminate greenhouse gas emissions (especially if methane emission from the production and transport of natural gas are not drastically reduced). Being the smallest molecule, hydrogen is much more prone to leak than methane. Last but not least: converting green electricity to hydrogen has an efficiency of about 70 % only. Subsequent steps usually imply a further loss of energy. Such energy losses increase the cost of using hydrogen.

30 European Commission, “A Hydrogen Strategy for a Climate-Neutral Europe,” Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions (Brussels, July 8, 2020), https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf.

31 Blue hydrogen is created from fossil sources, where the carbon emissions are captured and stored (CCS). Green hydrogen is made from non-fossil sources. Grey hydrogen is produced using fossil fuels.

32 Gasunie, “Infrastructure Outlook 2050,” Gasunie, 2019, https://www.gasunie.nl/en/expertise/system-integration/infrastructure-outlook-2050.

Excluding its advantages regarding climate, hydrogen is just not as good a package as fossil fuels. Costs are relatively high. As an energy carrier in a new energy system, it will have to fight for market share. It will carve out a role for decarbonising those parts of the energy system where zero carbon electricity (including batteries, flexible demand, and oversupply from wind and solar based electricity) is not a better option.

Uncertainty on future market share

Currently, hydrogen is primarily used in refining, to remove sulphur and other impurities, and in the petrochemical industry to produce fertilizer or plastic. The recent IMO (International Maritime Organization) regulation for shipping implies a greater demand for low sulphur shipping fuels, resulting in an increase of hydrogen demand. Present hydrogen production is almost exclusively grey hydrogen, mostly using natural gas (apart from China where coal is often used).

For different studies, the future share of hydrogen in the 2050 global energy supply varies between about 5 and 30 %.[33] This reflects the uncertainty in future costs for electrolysers, low-carbon electricity, natural gas, CO_2 pricing, Carbon Capture and Storage (CCS) as well as political choices. The role of hydrogen in our future energy system is relatively uncertain. Hydrogen is at a stage where electricity from solar and wind were 20 years ago: large potential, large uncertainties.

For a number of potential applications, hydrogen is likely to play an essential or at least important role. Studies from e.g., Rystad[34], IEA[35] or IRENA[36] tend to see industrial heat, steel production and long-distance shipping and aviation as areas where this will be the case, either directly for hydrogen or for derivates from hydrogen such as ammonia and synthetic fuels. With these applications, and a limited role for hydrogen in other areas, the demand for hydrogen in 2050 could increase by a factor of approximately 5. This would result in a hydrogen share of the global energy mix of about 10-15 %. Biofuels could be an alternative for some of these applications but the limited biofuel volumes that can be produced are expected to remain a constraint.

For a number of other applications, hydrogen is likely to play a small, perhaps even negligible, role. By now it is virtually certain that cars and light trucks will be electric. The role of hydrogen here, if any, will be limited to heavy trucks for long-distance road transport. For electricity, the role of hydrogen will be limited to ensuring power during *Dunkelflaute's* and winter cold snaps (whereas short cycle power backup will be done with batteries). For heating in buildings, electricity (heat pumps), in combination with geothermal heat and biogases, will leave limited room for hydrogen. For transport and heating in the built environment, the limited energy efficiency of hydrogen plays a major role. The total amount of energy needed for heating with hydrogen is about a factor 5 higher than that for electricity (and costs are higher by a factor of two).

33 Simon Evans and Josh Gabbatiss, "In-Depth Q&A: Does the World Need Hydrogen to Solve Climate Change?," Carbon Brief, 2020, https://www.carbonbrief.org/in-depth-qa-does-the-world-need-hydrogen-to-solve-climate-change.

34 Rystad Energy, "3rd Energy Transition Report: Hydrogen's CO2 Intensity, Vehicles Cost, Refinery Demand, Growth Markets, Production Costs and Energy Needs," Rystad Energy, March 2021, https://www.rystadenergy.com/newsevents/news/press-releases/3rd-energy-transition-report-hydrogens-co2-intensity-vehicles-cost-refinery-demand-growth-markets-production-costs-and-energy-needs/.

35 IEA, "The Future of Hydrogen," Technology report (Paris: IEA, 2019), https://www.iea.org/reports/the-future-of-hydrogen.

36 IRENA, "World Energy Transitions Outlook: 1.5°C Pathway (Preview)" (IRENA, March 2021), /publications/2021/March/World-Energy-Transitions-Outlook.

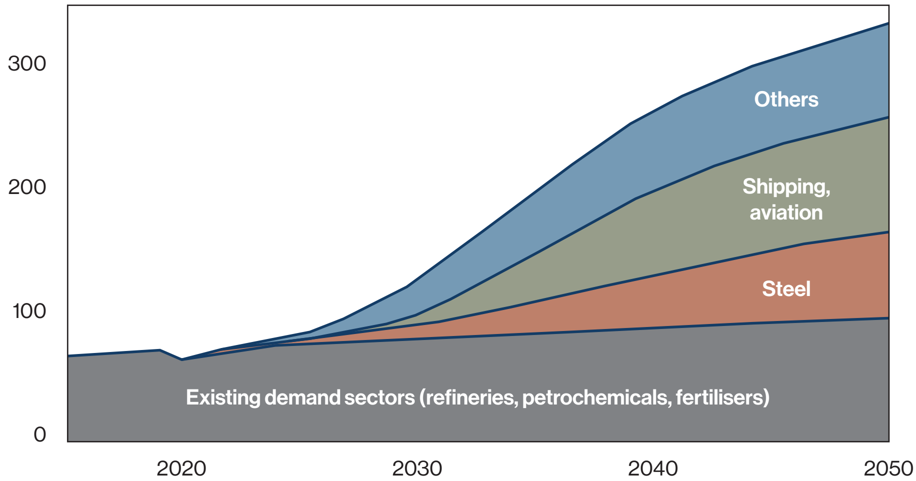


Figure 7: Worldwide demand for hydrogen in Mton per year. Others represent a number of potential applications (road transport, power, heating of buildings) that could potentially give rise to a much higher growth but for which it currently seems likely that hydrogen will play a relatively small role. (Source: Rystad).[37]

Future hydrogen costs

Green hydrogen costs will decrease when IEA and Goldman Sachs, the lowest costs of green hydrogen are expected in regions with large potential for low cost electricity from solar (e.g., North Africa and the Middle East). There, green hydrogen costs are expected to be close to the cost of blue hydrogen by 2030. Lowest production costs in such areas do not yet result in the lowest cost when delivered in e.g., NW Europe. Here, locally produced blue hydrogen is expected to have the lowest cost for the foreseeable future.[38]

To what extent and how quickly long-distance transport of hydrogen will take off remains unclear. Transport by ship incurs substantial costs. For such transport it is likely that hydrogen will be converted to ammonia or a LOHC (liquid organic hydrogen carrier), such as methanol or toluene. Ammonia has the advantage of the lowest costs (and most schemes, such as the recently announced NEOM project in Saudi Arabia, are planning for ammonia) whereas LOHCs are easier to handle and store in existing storage facilities. Estimates for the distance at which shipping will become less costly than transport by pipeline vary between about 1500 and 4000 km.

Figure 8 shows the IEA estimates of long-term costs for locally produced and imported hydrogen. It should be noted that these costs are subject to considerable uncertainty. Estimates for blue hydrogen include a CO_2 price of $100 / ton CO_2.

37 Rystad Energy, "3rd Energy Transition Report."

38 Michael Libreich, "Liebreich: Separating Hype from Hydrogen – Part One: The Supply Side," *BloombergNEF* (blog), October 8, 2020, https://about.bnef.com/blog/liebreich-separating-hype-from-hydrogen-part-one-the-supply-side/; Michael Libreich, "Liebreich: Separating Hype from Hydrogen – Part Two: The Demand Side," *BloombergNEF* (blog), October 16, 2020, https://about.bnef.com/blog/liebreich-separating-hype-from-hydrogen-part-two-the-demand-side/.

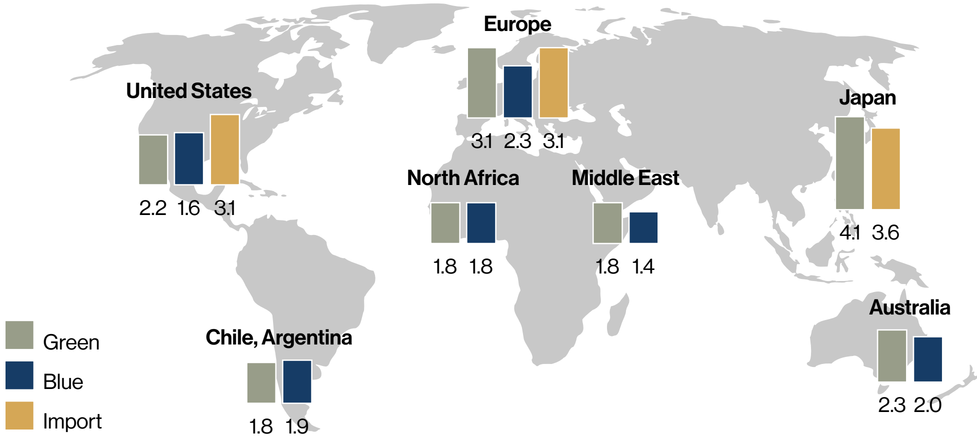


Figure 8: Estimate of the long-term costs of hydrogen (in $/kg) (source: IEA, The future of hydrogen[39]).

Whilst noting that uncertainties for future hydrogen costs remain large, one can try to sketch out how a future hydrogen production and transport system could look like:

- It seems likely that the production of hydrogen will take place on a more global and distributed basis than the current production of natural gas.
- Large scale hydrogen imports seem attractive for Japan (based on cost estimates for green hydrogen and space limitations) and, potentially, for NW Europe (depending on demand, based on space limitations).
- For countries with substantial natural gas reserves such as Russia and Qatar, the local production (and export) of blue hydrogen will be an attractive option. Depending on political choices this may also be the case for the US.
- For regions with the largest potential for low-cost electricity from solar (North Africa, Middle East, Australia), local production of green hydrogen will be an attractive option. To what extent this will result in large scale exports is still unclear.
- Europe has a preference for green hydrogen, whether locally produced or imported.

Hydrogen in the Netherlands

For the Netherlands, blue hydrogen and CCS projects, such as the Porthos[40] and H-Vision[41] projects near Rotterdam are an opportunity to rapidly diminish industrial CO_2 emissions. Blue hydrogen and CCS have more overlap with the existing strong points of the Dutch economy than green hydrogen. Developing an industry for building electrolysers will be a challenge, already for countries like Germany, let alone for the Netherlands. The Netherlands has the infrastructure, knowledge, industrial base and proximity to the North Sea (where empty gas fields have ample space for CCS) to kick start blue hydrogen production and CCS.

Blue hydrogen (and CCS) has an acceptance problem in the Netherlands; green hydrogen has a cost problem. As long as electricity in the Netherlands is not close to zero carbon, producing green hydrogen will not result in emission reductions.

39 IEA, "The Future of Hydrogen."

40 Porthos, "CO2 Reduction through Storage beneath the North Sea," Porthos, accessed April 12, 2021, https://www.porthosco2.nl/en/.

41 "H-Vision," H-Vision, accessed April 12, 2021, https://www.h-vision.nl/en.

Support for green hydrogen and support for blue hydrogen have different objectives. Supporting blue hydrogen is about a rapid reduction of industrial CO_2 emissions and building or extending hydrogen infrastructure. Supporting green hydrogen is about being part of a global effort to reduce the cost of electrolyzers, simply by starting to build them in large numbers. It is about preparing for major emission reductions from green hydrogen in the post-2030 period, once that zero-carbon electricity is readily available.

The Netherlands, and the Rotterdam area in particular, has a dominant position in crude oil and oil products, including storage, in NW Europe. It is not a given that this dominant position in oil will be transformed to a dominant position in hydrogen. The Netherlands will need to make a serious effort for this. Shell currently building its major hydrogen plant in Germany and Equinor shifting its focus outside Norway for hydrogen and CCS towards the UK (Teesside) are sources of concern. So far, Dutch government's financial support for hydrogen and/or CCS has been relatively small compared to that in Germany, the UK and Norway. In April 2021, the Dutch National Growth Fund allocated to a maximum of € 338 million to a project to accelerate the use of green hydrogen in chemistry, transport and heavy industry by innovation in the production and application of green hydrogen.[42] Sufficient storage capacity is essential if the Netherlands wants to achieve its ambitions.

4.5. **Biofuels**

Biofuels such as ethanol or biodiesel are made from biomass in the form of plant material or organic waste. Biofuels are particularly important for the transition of the transport industry away from fossil fuels.[43] Their advantage lays in the fact that unlike other renewable energy sources, biomass can be converted directly into liquid or gaseous fuels.[44] The United States is the largest producer of biofuels, followed by Brazil and the EU.[45]

Until now, biofuels have been blended with conventional petroleum fuels in the transportation sector, but they can also be used by themselves. Under the Sustainable Development Scenario, the IEA foresees an increased importance of biofuels for decarbonizing transport, particularly in developing countries, up to 2040. After that, however, the role of biofuels will be overshadowed by the electrification of powertrains, hydrogen and synthetic fuels. While they are now primarily used as alternatives to road transport, the roles of biodiesel and ethanol in the following decades will shift toward decarbonizing the maritime and aviation sectors.[46]

The large-scale deployment of biofuels depends on several factors. The production of biofuels is strongly influenced by the price of feedstock, while its competitiveness is dependent on global oil prices.[47] Policy support is another key factor impacting the future use of biofuels, and it varies as a result of sustainability concerns associated with conventional biofuels.[48] These are based on oilseed, sugar and starchy crops, which compete for

42 Ministerie van Economische Zaken en Klimaat and Ministerie van Financiën, "Kabinet trekt 646 miljoen euro uit voor economische groei" (Ministerie van Algemene Zaken, April 9, 2021), https://www.rijksoverheid.nl/actueel/nieuws/2021/04/09/kabinet-trekt-646-miljoen-euro-uit-voor-economische-groei.

43 IEA, "Energy Technology Perspectives 2020," 2020, 137.

44 Ministerie van Economische Zaken en Klimaat, "Biofuels for Transport," Government of the Netherlands, accessed April 7, 2021, https://www.government.nl/topics/environment/biofuels-for-transport.

45 OECD/FAO, "Biofuels," in *OECD-FAO Agricultural Outlook 2020-2029*, 2020, 200.

46 IEA, "Energy Technology Perspectives 2020," 158.

47 IEA, 139.

48 IEA, 137.

agricultural land with food crops. Land-use change, and biodiversity issues have also been associated with conventional biofuels. Advanced biofuels are based on technologies that mitigate sustainability issues but are still being tested and thus not yet commercially available. The US and EU have established policies that limit the consumption of biodiesel and ethanol as a result of these environmental issues. The use of conventional biofuels in the US and EU is thus expected to decrease below current levels.[49] Advanced biofuels, however, are seen as important in decarbonizing transport until at least 2030 under the EU's Renewable Energy Directive and the Dutch Climate Agreement.[50] Promoting the use of advanced, sustainable biofuels requires sufficient storage capacity.

49 OECD/FAO, "Biofuels," 197.

50 IEA, "The Netherlands 2020," 123.

5. **Outlook for the tank storage sector**

The need for the tank storage sector to adapt and reposition itself in a rapidly changing marketplace is manifest. An ever-increasing number of operators declare zero-carbon ambitions, influencing the service industry and forcing them to make strategic choices. The energy transition and ESG factors will shape investment decisions.

> "Energy transition is where the growth is in the medium term. Oil and gas will continue in the Middle East for the next 20-30 years but eventually decline. Growth will come from alternative energy."[51]

Many questions remain unanswered within the scope of this paper.

- How will the decreasing importance of oil and oil products impact the international trading industry and storage capacity?
- How will international oil companies adapt to the energy transition and what is their role in the trading sector?
- How does the increasing importance of Asian LNG markets impact Europe's ability and need to store LNG?
- How does the decarbonization of the industries in Europe and Asia impact the European tank storage sector?
- Today hydrogen is usually stored and delivered in compressed gas or liquid form. What are future storage options for hydrogen and hydrogen carriers?
- To what extent will hydrogen be deployed on a larger scale and how will this new product develop into a globally traded energy commodity?
- Will investment in hydrogen and ammonia infrastructure to import and distribute the commodities at large scale take off in the main energy and industrial demand centers?
- What will be the impact of electricity storage on conventional tank terminals?
- How can advanced biofuels contribute to the decarbonization of the maritime and aviation industries and to what extent will this happen?
- Will CCS become a business model? CCS providers like the *Northern lights project* have the ambition to accelerate decarbonization.[52] Is CO_2 storage capacity necessary once CO_2 shipping takes off? How will the regulatory framework around the capture and storage of CO_2 develop?

51 PwC, "Time to Choose: Oil Services at a Strategic Crossroads," PwC, 2021, https://www.strategyand.pwc.com/gx/en/insights/2021/pathways-for-oil-services.html.

52 "Accelerating Decarbonisation," Northern Lights, accessed April 12, 2021, https://northernlightsccs.com/.

6. **Concluding remarks**

New challenges that will impact the global energy economy as well as geopolitics are emerging. The international power relations and competition, influenced by geography, will also be affected. Will the geopolitical vulnerabilities shift from physical trade bottlenecks, such as the Strait of Hormuz, to electricity infrastructures and cybercrime? To what extent, in the short and medium term, do current dependencies on gas-producing countries make Europe vulnerable to the influence of power politics? As the transition to renewable energy accelerates, can the new technological developments in raw materials also be used to exert geopolitical influence? To ensure secure and affordable supplies of energy to the EU, diverse supply routes are needed to decrease the dependence on a single supplier of natural gas and other energy resources. Additionally, how will the role and structure of national strategic reserves be impacted by a new energy system?

The geopolitical consequences of a global transition to renewable energy have barely been mapped. Cartels could develop around materials essential to clean energy technologies; for oil and gas producers, a drop in revenues could spur political reforms and economic diversification, but it could also lead to political instability.

The strategic positioning of the tank storage sector in a socially, politically and financially advantageous situation depends on the impacts of the global context on the relevant supply chains. While numerous plans aimed at ensuring a smooth energy transition are being developed, policies are still weak, and scenarios vary. It is unclear whether the goals of the Paris Agreement, EU Green Deal or Dutch Climate Agreement can be adequately achieved. The political discourse is strong but the actions of even the world's strongest economies are not urgent enough. The high degree of uncertainty regarding the years to come could eventually materialize into a chaotic and abrupt transition from fossil fuels. Like any major change, the energy transition will create winners and losers. Those actors with strong, well-designed strategies allowing them to adapt to new realities will continue to gain. Resilience is not easily built nor maintained, and will require innovative, flexible and constantly adapted solutions. Contributing to resilience is also a comprehensive understanding of the global context and of the ways in which each product's supply chain – whether oil, gas or hydrogen – will develop.

7. Next steps

The global energy transition will undoubtedly bring challenges for states and companies alike, changing the global power balance and the architecture of economies. The tank storage sector can be part of the solution to these challenges. While the products in storage will change, storage can continue functioning as an essential component of the new energy system. Storing e-fuels, ammonia, flow batteries, bio kerosene and e-kerosene, are some of the emerging roles of tank storage. The sector should invest in innovation, resilience and adaptation strategies.

Becoming part of the solution will require collaboration and cooperation between storage companies to establish a unified position. The tank storage sector should ally with stakeholders such as port authorities, investors, and other actors along the supply chains of fuels and chemicals. Such outreach will be necessary to develop a common strategy and to gain a much stronger position in negotiating with political actors. Once a shared strategy is formulated, engagement with local, national and EU political stakeholders should be organized in order to enhance awareness of the potential of the sector to support the energy transition and its economic value. Most importantly, cooperation with stakeholders and political leaders will emphasize the need for a well-orchestrated transition strategy, focusing on long term goals, preventing unnecessary disinvestments as well as securing the required strategic energy storage.

References

Northern Lights. "Accelerating Decarbonisation." Accessed April 12, 2021. https://northernlightsccs.com/.

Blas, Javier, and Jack Farchy. *The World For Sale: Money, Power, and the Traders Who Barter the Earth's Resources*. Oxford University Press, 2021.

DNV GL. "New Directions, Complex Choices: The Outlook for the Oil and Gas Industry in 2020," 2020. https://brandcentral.dnvgl.com/fr/gallery/10651/others/4f3e1127a113440b8cef2ea87e273b9a/4f3e1127a113440b8cef2ea87e273b9a_low.pdf.

Equinor. "Energy Perspectives 2020: A Time of Great Uncertainty," 2020. https://www.equinor.com/en/sustainability/energy-perspectives.html.

European Commission. "A European Green Deal." Text. Priotities 2019-2024 - European Commission, 2020. https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_en.

———. "A Hydrogen Strategy for a Climate-Neutral Europe." Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. Brussels, July 8, 2020. https://ec.europa.eu/energy/sites/ener/files/hydrogen_strategy.pdf.

Evans, Simon, and Josh Gabbatiss. "In-Depth Q&A: Does the World Need Hydrogen to Solve Climate Change?" Carbon Brief, 2020. https://www.carbonbrief.org/in-depth-qa-does-the-world-need-hydrogen-to-solve-climate-change.

FETSA. "Tank Terminals in Europe - Key Figures," 2018.

———. "Tank Terminals in Europe - Key Figures," 2019.

Gasunie. "Infrastructure Outlook 2050." Gasunie, 2019. https://www.gasunie.nl/en/expertise/system-integration/infrastructure-outlook-2050.

H-Vision. "H-Vision." Accessed April 12, 2021. https://www.h-vision.nl/en.

IEA. "Energy Technology Perspectives 2020," 2020.

———. "Natural Gas." IEA Atlas of Energy, 2020. http://energyatlas.iea.org/#!/tellmap/-1165808390.

———. "Oil 2021." Paris: IEA, 2021. https://www.iea.org/reports/oil-2021.

———. "Oil Demand in the Petrochemicals, Industry and Buildings Sectors in the Stated Policies Scenario, 2019-2030." IEA, October 12, 2020. https://www.iea.org/data-and-statistics/charts/oil-demand-in-the-petrochemicals-industry-and-buildings-sectors-in-the-stated-policies-scenario-2019-2030.

———. "Projected Costs of Generating Electricity 2020." Paris: IEA, 2020. https://www.iea.org/reports/projected-costs-of-generating-electricity-2020.

———. "The Future of Hydrogen." Technology report. Paris: IEA, 2019. https://www.iea.org/reports/the-future-of-hydrogen.

———. "The Netherlands 2020." Energy Policy Review, 2020.

———. "World Energy Outlook 2020." Paris: IEA, 2020.

IRENA. "A New World: The Geopolitics of the Energy Transformation." IRENA, January 2019. /publications/2019/Jan/A-New-World-The-Geopolitics-of-the-Energy-Transformation.

———. "World Energy Transitions Outlook: 1.5°C Pathway (Preview)." IRENA, March 2021. /publications/2021/March/World-Energy-Transitions-Outlook.

Libreich, Michael. "Liebreich: Separating Hype from Hydrogen – Part One: The Supply Side." *BloombergNEF* (blog), October 8, 2020. https://about.bnef.com/blog/liebreich-separating-hype-from-hydrogen-part-one-the-supply-side/.

———. "Liebreich: Separating Hype from Hydrogen – Part Two: The Demand Side." *BloombergNEF* (blog), October 16, 2020. https://about.bnef.com/blog/liebreich-separating-hype-from-hydrogen-part-two-the-demand-side/.

Ministerie van Economische Zaken en Klimaat. "Biofuels for Transport." Government of the Netherlands. Accessed April 7, 2021. https://www.government.nl/topics/environment/biofuels-for-transport.

———. "Klimaatakkoord." Den Haag, June 28, 2019. https://www.klimaatakkoord.nl/documenten/publicaties/2019/06/28/national-climate-Agreement-the-netherlands.

Ministerie van Economische Zaken en Klimaat, and Ministerie van Financiën. "Kabinet trekt 646 miljoen euro uit voor economische groei." Ministerie van Algemene Zaken, April 9, 2021. https://www.rijksoverheid.nl/actueel/nieuws/2021/04/09/kabinet-trekt-646-miljoen-euro-uit-voor-economische-groei.

MIT Energy Initiative. "The Future of Nuclear Energy in a Carbon-Constrained World." MIT, 2018. https://energy.mit.edu/research/future-nuclear-energy-carbon-constrained-world/.

Mitrova, Tatiana, and Vitaly Yermakov. "Russia's Energy Strategy-2035: Struggling to Remain Relevant." Russie.NEI. Reports. Ifri, December 10, 2019. https://www.ifri.org/en/publications/etudes-de-lifri/russieneireports/russias-energy-strategy-2035-struggling-remain.

OECD/FAO. "Biofuels." In *OECD-FAO Agricultural Outlook 2020-2029*, 2020.

Porthos. "CO2 Reduction through Storage beneath the North Sea." Porthos. Accessed April 12, 2021. https://www.porthosco2.nl/en/.

PwC. "Time to Choose: Oil Services at a Strategic Crossroads." PwC, 2021. https://www.strategyand.pwc.com/gx/en/insights/2021/pathways-for-oil-services.html.

Royal Dutch Shell. "Shell LNG Outlook 2021." Royal Dutch Shell, 2021. https://www.shell.com/energy-and-innovation/natural-gas/liquefied-natural-gas-lng/lng-outlook-2021.html.

Rystad Energy. "3rd Energy Transition Report: Hydrogen's CO2 Intensity, Vehicles Cost, Refinery Demand, Growth Markets, Production Costs and Energy Needs." Rystad Energy, March 2021. https://www.rystadenergy.com/newsevents/news/press-releases/3rd-energy-transition-report-hydrogens-co2-intensity-vehicles-cost-refinery-demand-growth-markets-production-costs-and-energy-needs/.

Tank Terminals. "Shell's Oil Trading Profit Doubled in 2020," March 15, 2021. https://tankterminals.com/news/shells-oil-trading-profit-doubled-in-2020/.

Tennet. "Systeemintegratie belangrijk om klimaatdoelen te halen." Tennet, February 15, 2019. https://www.tennet.eu/nl/nieuws/nieuws/systeemintegratie-belangrijk-om-klimaatdoelen-te-halen/.

TNO. "Scenario's Voor Klimaatneutraal Energiesysteem." TNO. Accessed April 12, 2021. https://www.tno.nl/nl/aandachtsgebieden/energietransitie/roadmaps/systeemtransitie/de-sociale-aspecten-van-de-energietransitie/scenario-s-voor-klimaatneutraal-energiesysteem/.

US Energy Information Administration. "Oil and Petroleum Products." EIA, October 26, 2020. https://www.eia.gov/energyexplained/oil-and-petroleum-products/where-our-oil-comes-from.php.

Vopak. "Roadshow Presentation Q1." 05 2018. https://www.vopak.com/system/files/vopak_q1_2018_roadshow_presentation_1_0.pdf.

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