World Energy Council Austria

Young Energy Professionals (YEP)

Endbericht

Arbeitsgruppe:

Öl & Gas

Titel:

Transition Of The Oil & Gas Sector- The Global Goal To Achieve Climate Neutrality By 2050 - What Role Can The Oil & Gas Sector Play?

Januar 2024

ÜBER YOUNG ENERGY PROFESSIONALS

Die Young Energy Professionals (YEP) bilden das interdisziplinäre Netzwerk junger Berufstätiger im WEC Austria. Gegründet “von jungen Menschen für junge Menschen” auf dem Weltenergiekongress 2007 in Rom, sind die Ziele der Young Energy Professionals

- faktenbasiert Wissen zu energiewirtschaftlichen Themen zu vermitteln,
- ein fachlich übergreifendes Netzwerk aufzubauen,
- junge Entscheidungsträger und Meinungsbildner sowie den energiewirtschaftlichen Nachwuchs anzusprechen,
- Erfahrungs- und Wissensaustausch innerhalb des WEC-Netzwerks zu ermöglichen sowie
- die internationalen Aktivitäten der Future Energy Leaders Community von WEC zu unterstützen.

WEC Austria beschloss im Jahr 2015 eine nationale YEP-Gruppe zu etablieren. Zum einen unterstützen die YEP von WEC Austria die Arbeiten der internationalen Nachwuchsorganisation des World Energy Council. Zum anderen werden auf nationaler Ebene Lösungsvorschläge zu verschiedenen energiewirtschaftlichen Fragestellungen erarbeitet. Hierbei deckt ein interdisziplinärer Pool an jungen Berufstätigen der Energiewirtschaft vielfältige Themenbereiche ab. Ein Board unterstützt und begleitet die YEP.

Auf internationaler Ebene treffen sich die YEP zwei Mal im Jahr auf Einladung eines Mitglieds. Auf internationaler und nationaler Ebene finden zudem Telefonkonferenzen und Netzwerktreffen statt.

Ein YEP Zyklus dauert etwa drei Jahre. Danach werden die YEP Programmteilnehmer in die YEP-Alumni-Community aufgenommen.

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Vorwort

Wir stehen an der Schwelle zu einer neuen Ära der Energiepolitik, in der Österreich eine führende Rolle bei der Dekarbonisierung seines Energiesystems spielen kann. Dieser Prozess ist komplex und herausfordernd, da er eine grundlegende Umgestaltung in der Energieerzeugung, im Verbrauch und in der Politik erfordert. In der zukünftigen Energieversorgung wird der Öl- und Gasbereich durch die Entwicklung von Technologien wie CCUS und Wasserstoff neu definiert.
Dieses Wissen kann die Entwicklung und Einführung erneuerbarer Energietechnologien im Rahmen des Energiewandels unterstützen.

Der folgende Bericht unserer Young Energy Professionals, mit dem Titel „Transition Of The Oil & Gas Sector- The Global Goal To Achieve Climate Neutrality By 2050 - What Role Can The Oil & Gas Sector Play?", analysiert und diskutiert diese Thematik anhand umfassender Ansätze mit dem Bezug zur österreichischen Situation. Mit diesem Bericht wird ein umfassender Einblick in die komplexen Herausforderungen und möglichen Lösungsansätze der Energiepolitik geboten und damit ein wertvoller Beitrag zur Diskussion und zum Verständnis dieses wichtigen Themas geleistet.

Ich wünsche eine spannende und anregende Lektüre!

Dr. Michael Strugl

Präsident WEC Austria

ARBEITSGRUPPE

Öl & Gas

TITEL DER ARBEIT

Transition Of The Oil & Gas Sector- The Global Goal To Achieve Climate Neutrality By 2050 - What Role Can The Oil & Gas Sector Play?

AUTOR*INNEN

Dipl.Ing. Dr. Christian Diendorfer[1], MBA
Dr.-Ing. Rafael E. Hincapie, MBA
Dipl.-Ing. Jasmin Mensik
Bojan Pejić, MSc
Thomas Schlager, MSc
Dipl.-Ing. Magdalena Teufner-Kabas, MSc

[1] Gruppenmitglied bis 31.7.2022

Über die Autor*innen

Dipl.-Ing. Dr. Christian Diendorfer PhD., MBA, arbeitet als Research Engineer am Austrian Institute of Technology, wo er an Dekarbonisierungsoptionen für die energie-intensive Industrie forscht. Zuvor war er in verschiedenen Funktionen in der Öl- und Gasindustrie tätig. Zusätzlich unterrichtet er an der FH Technikum Wien. Christian studierte Maschinenbau an der TU Wien und schrieb seine Dissertation über schwimmende Solaranlagen. An der WU Wien absolvierte er einen MBA mit der Vertiefung auf Energy Managment.

Dr.-Ing. Rafael E. Hincapie

Dipl.-Ing. Jasmin Mensik, arbeitet bei E-Control im Bereich Marktüberwachung der europäischen Strom- und Gasmärkte mit Fokus auf Lieferort Österreich. Dies beinhaltet die Analyse der Gebote und Handelsaufträge aber auch die aktive Mitarbeit an europäischen Arbeitsgruppen der Agentur für die Zusammenarbeit der Energieregulatoren (ACER). Das Studium im Bereich der Energietechnik absolvierte sie an der Universität für Bodenkultur (BOKU) in Wien. Zudem war sie als studentische Projektmitarbeiterin im Bereich erneuerbare Energien am Institut für Verfahrens- und Energietechnik der BOKU tätig. Im Zuge ihrer Dissertation beschäftigt sie sich seit 2022 verstärkt mit Energiespeichersystemen und deren Rolle in der Energiewende.

Bojan Pejić, MSc, arbeitet im Bereich Sales und Business Development bei Siemens Energy Austria GmbH. Das Maschinenbaustudium absolvierte er 2014 an der Universität Zagreb. Seit 2015 ist er in der Energiebranche tätig. Zunächst als Systemingenieur für Anlagenplanung, dann als Fachangebotsleiter für Planung und Bau industrieller GuD-Kraftwerke und derzeit als Field Sales Manager für Energieerzeugungsportfolio in der Region Südosteuropa.

Thomas Schlager, MSc, ist als Innovationsmanager bei der EVN AG verantwortlich für die Forschungs- und Entwicklungsstrategie und das Fördermanagement der EVN Gruppe. Zusätzlich ist er im Front Office Trading der EVN im operativen Dienst als Springer tätig. Nach seinem Masterabschluss für industrielle Elektronik verantwortete Thomas Schlager das Business Development der Firma Austrian Institute of Technology im Bereich Photovoltaic Systems.

Dipl.-Ing. Magdalena Teufner-Kabas, MSc, gegen Ende ihres Studiums Nachwachsende Rohstoffe an der Universität für Bodenkultur und der Technischen Universität München, arbeitete sie 5 Jahre am Austrian Institute of Technology an der Nutzung von Kohlendioxid (CO2) für die Herstellung von Chemikalien. 2015 gründete sie kleinkraft. Kleinkraft unterstützt Betriebe dabei von der Energiewende zu profitieren. Investitionen im Bereich Energieeffizienz und erneuerbare Energien nicht nur technisch, sondern auch wirtschaftlich lukrativ sein müssen. Aus diesem Grund kombiniert kleinkraft technische Beratung mit der entsprechenden Förderung oder dem entsprechenden Forschungsprojekt und unterstützt Unternehmen dabei, die Energiewende nicht nur technologisch zu meistern.

Danksagung

Die YEP-Arbeitsgruppe *Öl und Gas* möchte sich herzlich beim WEC Austria, insbesondere bei Dr. Robert Kobau und seinen Assistent:innen Milica Vujačić, MSc und Rupert Wimmer, MSc für die Organisation bedanken. Insbesondere hervorheben möchten wir die interessanten Veranstaltungen und Vorträge, welche in pandemiebedingt besonders herausfordernden Zeiten, möglich gemacht wurden.

Wir möchten uns auch bei unseren Mentoren Dipl.-Ing. Dieter Drexel und Prof. Dr. Stephan Unger für die Unterstützung bedanken. Gerade in der Anfangsphase der Gruppenarbeit hat Ihr Feedback maßgeblich dabei geholfen die Struktur festzulegen und somit eine gute Basis für die weitere Arbeit zu schaffen.

Inhaltsverzeichnis

ABSTRACT

The decarbonization of Austria's energy system is a multi-layered and challenging task which involves significant transformation in energy generation, consumption and policy. It is inevitable to reduce the use of fossil sources as the major causes of greenhouse gas emissions. To meet Paris Climate Goals it requires significant policy changes and investment to transition towards renewable energy sources. To address this challenge, we have to act at multiple layers (International Energy Agency, 2020; United Nations Development Programme, 2019). Carbon capture, utilization, and storage (CCUS) technologies have the potential to reduce carbon emissions from the oil and gas sector. However, limitations such as high implementation costs and environmental impacts must be considered (International Energy Agency, 2020). Green Hydrogen, based on renewable energy and electrolysis, can be an alternative for fossil sources in areas where decarbonization is exceptionally challenging like heavy transport or industry. Though limitations of green hydrogen production such as high energy consumption and conversion losses due to low efficiency must be considered (Kondili et al., 2021).

The oil and gas sector in the future energy system can be seen through the development of technologies such as CCUS and hydrogen. Another valuable aspect is the broad expertise of the oil and gas sector in areas like exploration and management of large-scale projects. This knowledge can support the development and deployment of renewable energy technologies in the energy transition (United Nations Development Programme, 2019).

1. Introduction

Dipl.-Ing. Dr. Christian Diendorfer, MBA

The global energy sector is currently in turmoil. The coincidence of several crises leads to short-term market dislocations and probably to massive long-term changes in the energy system. The main long-term challenge is climate change, which is the result of continuously increasing concentration of greenhouse gases (GHG) in the atmosphere. This increase of CO2 is primarily driven by burning fossil fuels like coal, oil and gas. However, also other GHGs like methane contribute significantly to climate change. According to the UN, the Earth is now already 1.1°C warmer than it was in the late 19th century. The global consequences of climate change include, among others, intense droughts, water scarcity, severe fires, rising sea levels, flooding, melting polar ice, catastrophic storms and declining biodiversity.

Scientists and governments have agreed that limiting global temperature rise to no more than 1.5°C would help to avoid the worst climate impacts and to maintain a liveable planet. The Paris Agreement, signed by 190 Parties in 2016, sets out the framework for limiting global warming “to well below 2°C and pursuing efforts to limit it to 1.5°C”.

To achieve the main objectives of the Paris Agreement, global GHG emissions need to peak as soon as possible and must be reduced rapidly thereafter to reach a balance between emissions and removals in the second half of the century.

While tackling climate change is already challenging on its own, economic disturbances caused by the COVID-19 pandemic and geopolitical tensions increase the complexity. Since the impact of climate change came to the political agenda, the main focus of policy makers was increasing sustainability by reducing GHG emissions in the energy sector. However, this one-sided focus has neglected the other two elements of the Energy Trilemma, namely energy equity and energy security. The consequences of the Russia-Ukraine conflict demonstrate the importance of a secure and diversified energy supply. High inflation rates, mainly due to rising energy prices, are a burden on households and businesses.

The current energy shortage in the EU jeopardizes the planned decarbonization of the energy sector, as policies aim for a short-term switch from natural gas to petroleum products and coal. Coal-fired power plants that have already been shut down are to be recommissioned, and industrial operations are to be converted to the use of oil wherever possible.

Currently[2], fossil fuels are still the backbone of the EU’s energy demand (Eurostat, 2022). Almost 70% of the energy available in the EU came from fossil sources in 2020. Petroleum products, which also includes crude oil, account with a share of 34.5% as the main energy source. The second largest energy source in the EU is natural gas with a share of 23.7%. Together, petroleum and natural gas are currently the source of over 58% of available Energy in the EU.

Looking at the mix of total available energy for Austria specifically, one can see, that the distribution amongst energy products is quite similar to the EU average. The share which is covered by nuclear energy in the EU is covered by an increased share if renewable energy in Austria. Petroleum products and natural gas account together for over 57% in Austria, demonstrating the still high dependence on fossil fuels.

Figure 1 shows the share of energy products in the total available energy for the EU and Austria for the year 2020.

[2] The latest available data at the time of writing this report is from 2020.

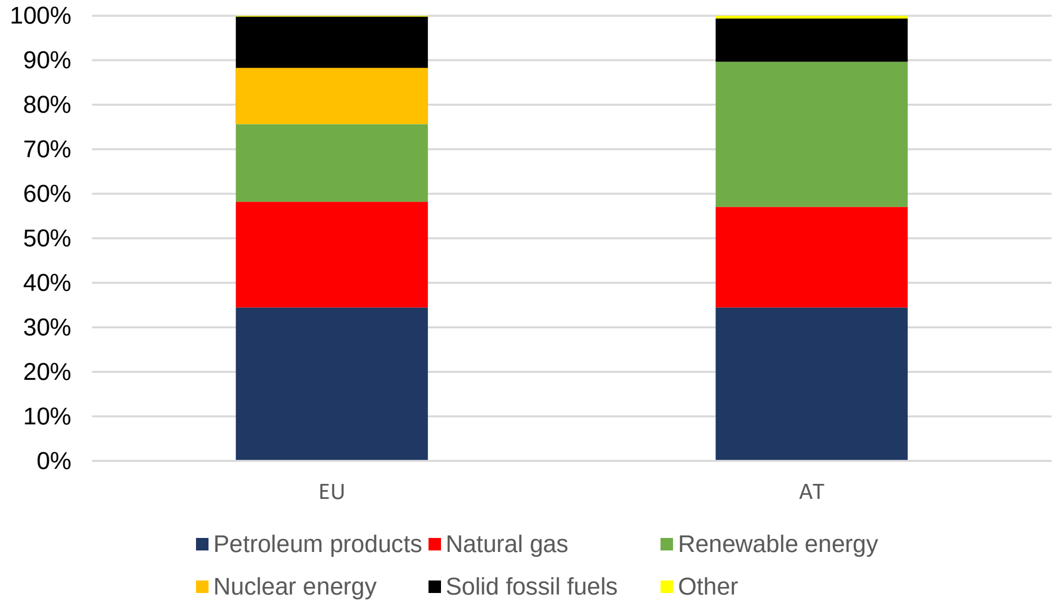


Figure 1 – Share of energy products in total energy available in 2020. (Eurostat, 2022a)

Recent geopolitical developments highlighted the importance of diversified sources for energy imports. The EU's dependency rate for energy imports was equal to 58% in 2020. This means that 58% of the EU's energy needs were met by net imports. Austria matches almost exactly the EU's average. The import dependency of the EU ranges from over 90% in Malta, Cyprus and Luxembourg to only 10% in Estonia.

Almost two thirds of the energy imported to the EU were in the form of petroleum products, with crude oil being the main component. Natural gas accounts for 27% and solid fossil fuels[3] for 5%.

29% of crude oil imports from outside the EU came from Russia. 9% from the US, 8% from Norway. Saudi Arabia and the UK both account for 7% and Kazakhstan and Nigeria for 6%, see Figure 2.

[3] 3 Various types of coals and solid products derived from coals.

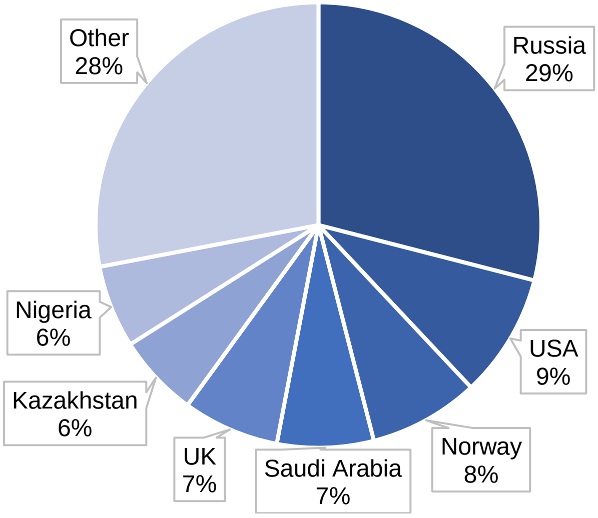


Figure 2 – Sources of crude oil imports to the EU, 2020. (Eurostat, 2022a)

Russia provided 43% of natural gas imports to the EU. 21% are imported from Norway, 8% from Algeria and 5% from Qatar (Figure 3).

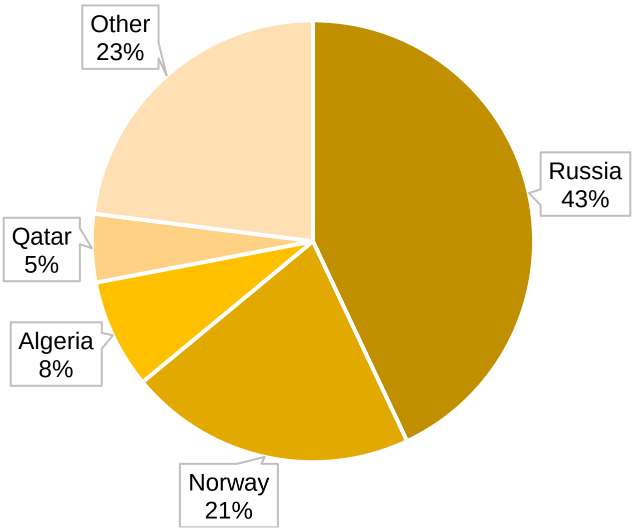


Figure 3 –Sources of natural gas imports to the EU, 2020. (Eurostat, 2022a)

Looking at solid fossil fuels, 54% originated from Russa, followed by the US with 16% and Australia with a share of 14%, see Figure 4.

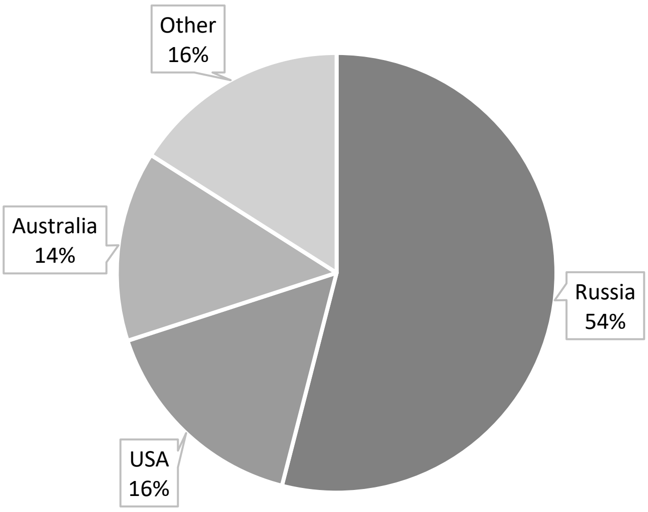
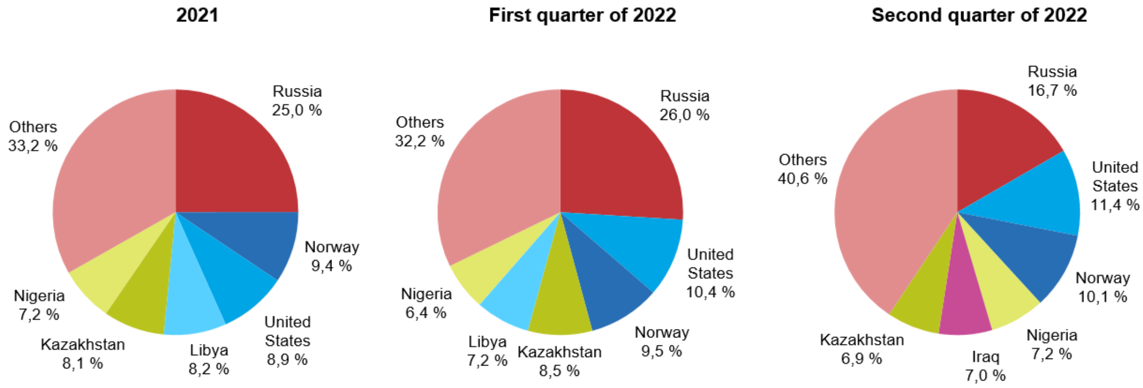


Figure 4 – Sources of solid fossil fuels imports to the EU, 2020. (Eurostat, 2022a)

Russia was the main source for types of fossil energy imports to the EU in the past. Due to recent developments these trade patterns have already changed significantly and further adaptations in the future are expected.

The most recent developments can be seen in Eurostat's trade data (Eurostat 2022b). It is important to highlight that these trade data are based on trade volume in monetary values and not in energy units. Due to recent price volatility, trade date might provide a distorted picture. At the time of writing, data on an energy level is only available until 2020.

Figure 5 shows the development of extra-EU imports of petroleum oil by trade partner since 2021. The share of Russia significantly decreased from 25% in 2021 to 16.7% in the second quarter of 2022.



Source: Eurostat database (Comext) and Eurostat estimates

Figure 5 – Extra-EU imports of petroleum oil by partner. (Eurostat, 2022b)

The development for natural gas is even more dramatic. While Russia had a share of almost 40% in 2021, this decreased to only 23% in the second quarter of 2022. At the same time, the shares of the United States increased by 10.2 percent points. The share of the United Kingdom increased by 8.4 percent points in trade volume.

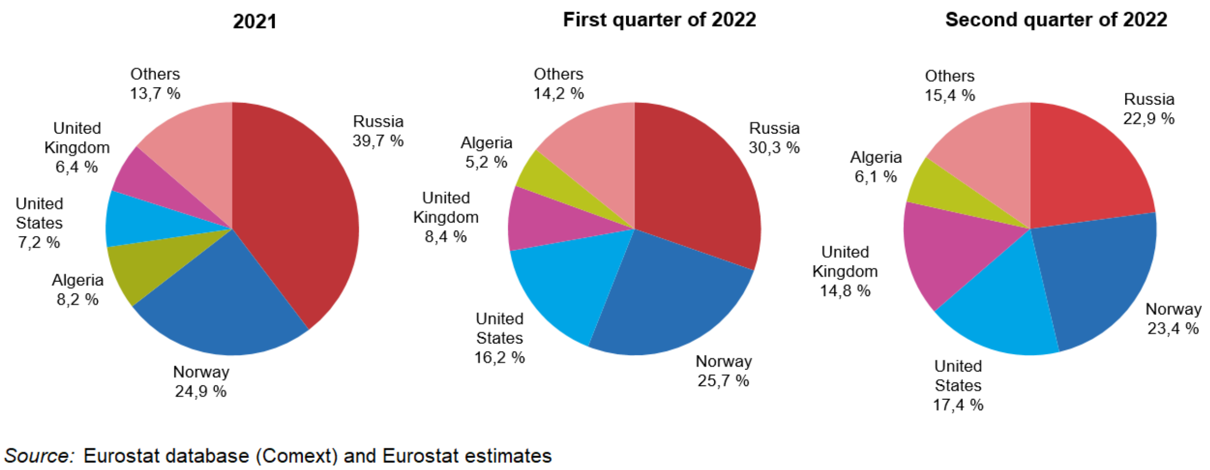


Figure 6 – Extra-EU imports of natural gas by partner. (Eurostat, 2022b)

Price spikes for natural gas significantly increased the costs of natural gas imports to the EU. While the amount of natural gas imported to the EU was quite stable in a range between 16.4 to 18.9 million tons per month, the costs have multiplied. In 2020 the EU imported natural gas worth € 3.2 billion per month. This increased to almost € 25 billion per month in the second quarter of 2022 (Figure 7). This raises the question if natural gas can still be considered as a low-cost fuel.

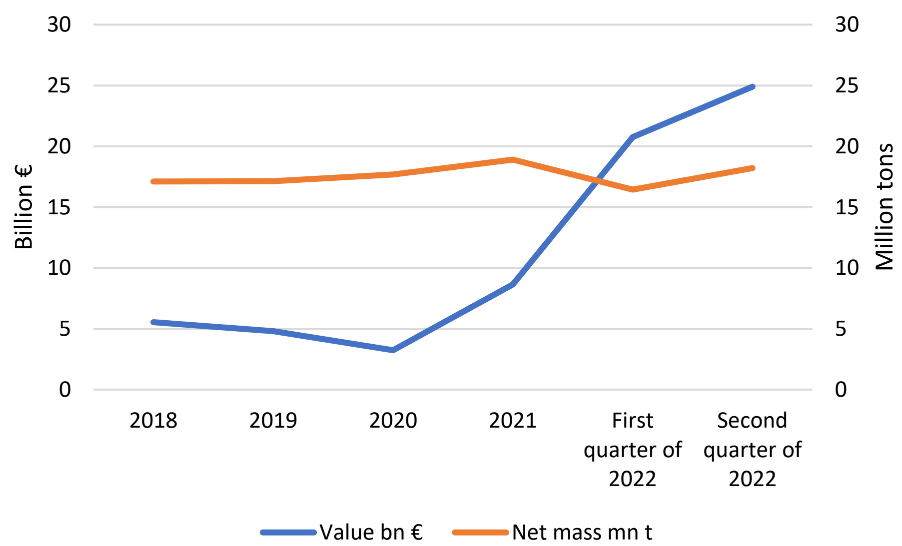


Figure 7 – Extra-EU imports of natural gas: Value vs. mass. (Data from Eurostat, 2022b)

In summary, the EU in general and Austria in particular are still highly dependent on oil and gas imports. The high share of fossil fuels in the energy mix corresponds to the importance of existing infrastructure and companies in the oil and gas sector.

A transition to net-zero emissions by 2050, which is the objective of the European Green Deal, will require a substantial transformation of the economy and will have a significant impact on the oil and gas sector.

The International Energy Agency (IEA) estimates in its Net Zero Emission scenario, which is presented in the report “Net Zero by 2050 – A Roadmap for the Global Energy Sector”, that global oil demand would need to collapse by 75% until 2050. The share of fossil fuels in the global energy mix would need to be reduced from currently 80% to 20% in 2050.

The IEA’s Net Zero Emission scenario would not require an exploration of new resources and no new oil fields would be required, except the ones already approved for development. However, the IEA acknowledges that still some investments into the existing fields would be required. Also, no additional natural gas fields would be required beyond those already producing or under development. The IEA projects, that many of the liquified natural gas (LNG) plants currently planned or already under construction would be stranded assets.

With a transition to renewable energies, the question now arises as to what will happen to the infrastructure, the companies and their employees. In this report, we attempt to address these questions and identify options for the oil and gas industry in a net-zero future.

2. Role of the Oil and Gas Sector in the Energy Transition

Dipl.-Ing. Dr. Christian Diendorfer, MBA

Thomas Schlager, MSc

Bojan Pejić, MSc

Status Quo: Oil Sector

In 2021, oil accounted for 34.5% of Austria's gross domestic consumption (BMK, 2022). Oil is also the main energy source imported to Austria. Austria imported 968.8 PJ of energy in 2021. Oil accounted for 58.5% of this amount. In contrast, natural gas represents only 17% of energy imports to Austria.

National production of oil is on a downwards trend, with an average annual decline of 3.1% since 2005. Oil accounts for 4.5% of Austria's primary energy production, which is higher than the EU-27 average of 3.7%.

Oil represents 386 PJ or 34.5% of Austria's final energy consumption. 81% of oil are consumed as fuel in the transport sector. Private households account for 11% of final oil consumption. Industry uses 4% of Austria's oil consumption. The service sector and agriculture are responsible for 2% of oil consumption. A significant amount of 75 PJ of oil is used in a non-energetic way, for example for the production of plastics and lubricants.

Oil plays only a minor role in Austria's power and district heating sector. 3% of district heat production and 1% of electricity production are coming from oil.

The dominance of oil in Austria's energy system is best visualized by the energy flow diagram published by the Austrian Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology, which is shown in Figure 8. In this Figure the oil stream is colored in red.

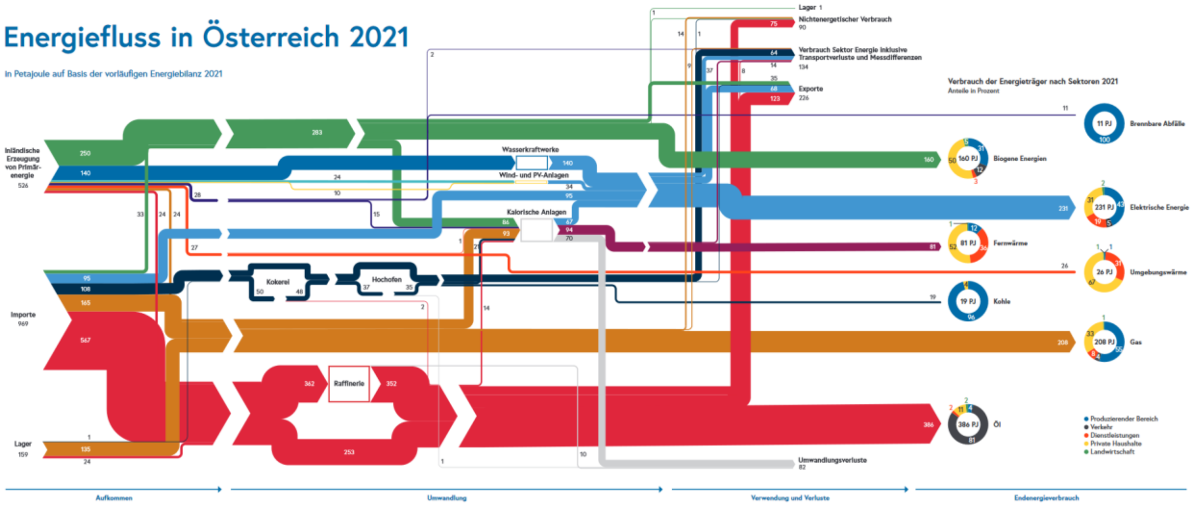


Figure 8 – Energy flow diagram for Austria in 2021. (BMK, 2022)

Between 2005 and 2021 gross domestic consumption of oil declined on average by 1.3% per year. Due to the recovery of the transport sector from the pandemic oil demand increased by 6.8% from 2020 to 2021. Energy consumption in Austria has stabilized during the last years with an average decline of 0.1% per year. As renewables are experiencing significant growth rates (PV: +35.8% p.a., Wind: 10.7% p.a., ambient heat: 8.1%), fossil energy sources are slowly substituted[4]. However, to achieve the ambitious climate targets the current pace will not be sufficient.

Status Quo: Gas Sector

According to Statistics Austria, 1055 PJ of final energy are consumed in Austria, of which 18.4% and therefore 194 PJ, are covered by gas. Most of the gas consumed can be attributed to the manufacturing sector with 56%, followed by private households with 31%, transport with 5% and services sector with 7%.

As a contribution to the achievement of the goals of the Paris Climate Protection Agreement 2015 and the goal of the European Union to cover at least 32% of the gross final energy consumption of the Union with renewable energy by 2030, as well as in the endeavor to achieve climate neutrality in Austria by 2040, 2021 the federal law on the expansion of energy from renewable sources (Erneuerbaren Ausbau Gesetz – EAG) was passed.

The Austrian federal government is therefore pursuing the goal of complete decarbonization of the energy and entire economic system by 2040. The European Commission also tightened its climate targets in July 2021 and is now aiming to reduce net GHG emissions by at least 55% by 2030 compared to 1990. With this intermediate goal, Europe should become the first climate-neutral continent in the world by 2050.

Approximately 40% of the global CO2 emissions are caused by power generation – see figure 10 below.

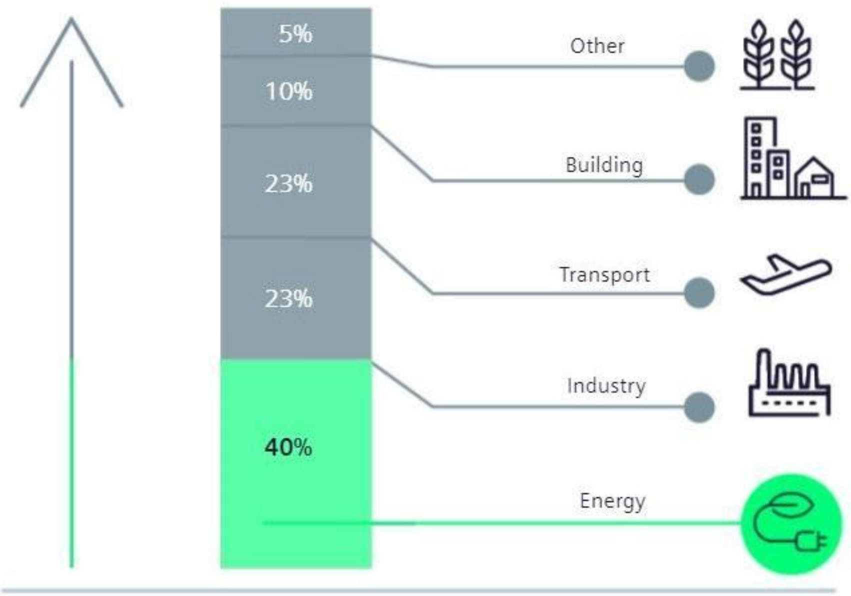


Figure 9 Global CO2 emissions by sector (IEA, 2018)

Coal-fired power plants emit around 10 Gt of CO_2 per year* (IEA (2021), World Energy Outlook 2021, IEA, Paris www.iea.org/reports/worldenergy-outlook-2021, p. 130) and are considered one of the largest emitters of greenhouse gases in the power generation industry. In order to help accelerating the shift from solid or liquid fossil fuels including coal towards a climate-

[4] However, renewables are growing from a much lower base compared to fossil energy sources.

neutral future, the European Commission published the Complementary Delegated Act (Eur-Lex, 2022) which approves, under strict conditions, specific nuclear and gas energy activities in the list of economic activities covered by the EU taxonomy. Although not climate neutral itself, natural gas is seen as a temporary alternative to replace the dirtier solid and liquid fuels which produce more planet-warming emissions. In order to reduce the climate impact of the new gas fired power and/or heat assets, the Complementary Delegated Act sets a number of technical screening criteria, including:

- The life-cycle GHG emissions from the generation of electricity using fossil gaseous fuels are lower than 100 g CO_2e/kWh

and facilities for which the construction permit is granted by 31 December 2030 have to comply with following:

- Direct GHG emissions of the activity are lower than 270g CO_2e/kWh of the output energy, or annual direct GHG emissions of the activity do not exceed an average of 550kg CO_2e/kW of the facility's capacity over 20 years
- The activity replaces an existing high emitting electricity generation activity that uses solid or liquid fossil fuels
- The facility is designed and constructed to use renewable and/or low-carbon gaseous fuels and the switch to full use of renewable and/or low-carbon gaseous fuels takes place by 2035
- The replacement leads to a reduction in emissions of at least 55 % GHG over the lifetime of the newly installed production capacity

The Figure 11 shows indicative CO_2 emission levels per produced kWh of electricity for various fuel types, as well as targets set within the Complementary Delegated Act. It is evident that although conventional gas-powered power plants produce significantly less CO_2 than coal and fuel oil power plants, they do not meet technical screening criteria set by the European Commission. Hence, in order to comply, mitigation measures will have to be implemented. Some of the mitigation measures will be discussed in the following chapter.

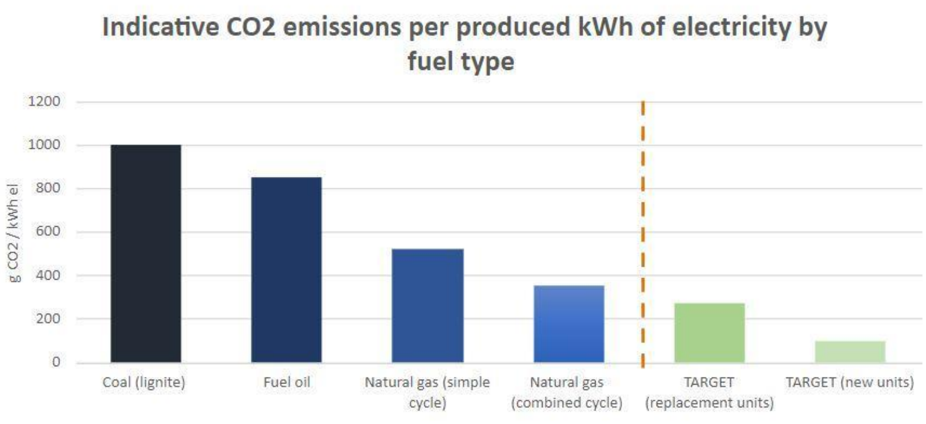


Figure 10 Indicative CO2 emission levels per produced kWh of electricity for various fuel types

Policy Orientation & Regulatory Framework

In its current government program, the Austrian federal government is pursuing the ambitious goal of completely decarbonizing the energy system and the entire economic system by 2040.

The EU presented the “European Green Deal” in 2019. This is an initiative to make the EU climate neutral by 2050 and to decouple economic growth from energy and resource consumption.

The European Commission also tightened its climate targets in July 2021 and now aims to reduce net GHG emissions by at least 55% by 2030 compared to 1990. With this interim target Europe is to become the world's first climate-neutral continent by 2050.

The target of climate neutrality was enshrined in the European Climate Law, which is in force since July 2021. The European Climate Law sets the legally binding targets of a net domestic greenhouse gas reduction by at least 55% by 2050 compared to 1990 levels. The law also contains the legally binding objective of climate neutrality by 2050. For the period after 2050, the EU commits to net-negative emissions.

The European Commission has published several regulatory proposals to update the EU’s climate and energy policies to achieve the targets enshrined in the European Climate law. The objective of these proposal is to make the EU’s climate and energy policy fit for a 55% reduction in greenhouse gas emissions by 2030, in line with the EU's recently strengthened climate targets. Hence, this set of proposals is called the “Fit-for-55 package”.

This update of EU’s climate and energy policy rests on three pillars. First, prices for greenhouse gas emissions should increase. A stricter Emission Trading System (ETS) and an extension of the ETS to the maritime and road transport as well as buildings sector will achieve this. An update of the Energy Tax Directive will increase the minimum tax on carbon-emitting fuels and change taxation from volume-based rates to energy-based rates. To ensure that products imported into the EU pay the same price for carbon emissions as products manufactured within the EU, a new Carbon Boarder Adjustment Mechanism will be implemented. This should prevent the migration of emissions-intensive industries to third countries.

Second, the European Commission aims for more ambitious emission and energy reduction targets in several areas. The targets of the Effort Sharing Regulation, which sets the national emission reduction targets for each Member State, will be strengthened. The Renewable Energy Directive will be updated with higher targets for the share of renewable energy in the European Union. The update of the Energy Efficiency Directive will ensure the implementation of energy efficiency measures across all sectors and set a cap on the EU’s energy demand. Additionally, stricter targets are set in the Land Use, Land Use Change and Forestry Regulation. This will ensure that carbon sinks from land use are not only protected but can make a significant contribution to the decarbonization of the continent.

Third, the European Commission proposes stricter regulations to support the reduction of greenhouse gas emissions. These include stricter CO_2 performance regulations for cars and vans, regulations to reduce the carbon intensity of marine fuels, and mandatory blending of sustainable aviation fuels in the aviation sector. The new Alternative Fuels Infrastructure Regulation shall ensure that sufficient charging and refueling infrastructure for low-emission fuels is available to support the energy transition. A significant share of the EU’s energy demand is used for heating and cooling of buildings. The revision of the Energy Performance of Buildings directive should improve the energy performance of buildings and increase the renovation rate of existing buildings. The recast of the Gas Regulation and Gas Directive aims at including renewable gases and hydrogen in the future European gas market.

While most proposals in this policy package have the potential to affect oil demand in one way or the other, the most direct impact can be expected from the proposal to implement stricter CO2 performance for cars and van, the RefuelEU Aviation and the FuelEU Maritime initiative.

The regulation on CO_2 emission performance for cars and vans sets an EU fleet-wide target of 95 g CO2/km for the average emission of new passenger cars and a fleet-wide target of 147 g CO2/km for the average emission of new light commercial vehicles registered in the EU from 1 January 2020 until 31 December 2020. From 1 January 2021, the targets are calculated based on a specified mechanism.

In the new proposal the fleet of newly registered cars has to reduce emissions by 55% by 2030 and by 100% by 2035 compared to 2021. For new vans, the reduction targets are 50% and 100%, respectively. This means a de facto ban on the sale of new gasoline and diesel cars from 2035 in the EU.

The RefuelAviation initiative aims to support a swift transition from fossil fuels towards sustainable fuels in air transport. It proposed EU-wide harmonized rules for Sustainable Aviation Fuels (SAFs). The European Commission acknowledge that zero emission aircrafts are not yet available and will not be widely used before 2035. Hence, the main option to reduce emissions from the aviation sector is to substitute conventional aviation fuel with SAFs. In 2025, the minimum share of SAF in aviation fuel should be 2%, increasing to 5% in 2030. For 2050, the minimum share of SAF would be set at 63%.

SAFs include advanced biofuels and synthetic fuels. Crop-based biofuels are explicitly excluded from the SAF definition. Also, Hydrogen and electricity are not considered as SAF.

FuelEU Maritime focuses on fuel consumption in the maritime sector. Maritime greenhouse gas emission are not explicitly included in the Paris Agreement. The European Parliament aims at moving away from the use of heavy fuel oil in the shipping sector. The proposal of the European Commission focuses on the reduction of greenhouse gas intensity of fuel used on board. The GHG intensity reduction targets are determined against the fleet average greenhouse gas intensity of energy used on-board by ships in 2020. Annual average GHG intensity should be reduced by 2% in 2025 and by 6% in 2030. In 2050, carbon intensity should decrease by 75% compared to 2020 levels. Additionally, passenger and container ships would be required to use onshore power supply while at berth unless they can demonstrate the use of another zero-emission technology from 2030 onwards.

The proposal accommodates all renewable and low-carbon fuels in maritime transport, such as liquid biofuels, e-liquids, decarbonized gas (including bio-LNG and e-gas), decarbonized hydrogen and decarbonized hydrogen-derived fuels (including methanol, and ammonia), as well as electricity. All GHG emissions that a fuel generates have to be taken into account (full lifecycle) and not only those generated on the ship.

With oil being one of the dominant carbon emitting energy sources in these sectors, these targets will significantly impact oil demand in Austria in particular but also the global oil industry as a whole. For the EU, the IEA projects in its Stated Policies Scenario (STEPS) a decline in oil demand from 9.2 mb/d in 2021 to 4.5 mb/d in 2050, see Figure 11. This scenario is a conservative approach that only considers policies and measures that have actually been put in place. In the Announced Pledges Scenario (APS), an oil demand reduction to 1.7 mb/d is projected. The APS aims to show how announced ambitions and targets affects the energy system. While for the EU a significant decline in oil demand is projected, it should be noted that on a global level oil demand is expected to increase from 94.5 mb/d in 2021 to 102.1 mb/d in 2050 in STEPS. The APS scenario projects a global decline to 57.2 mb/d by 2050.

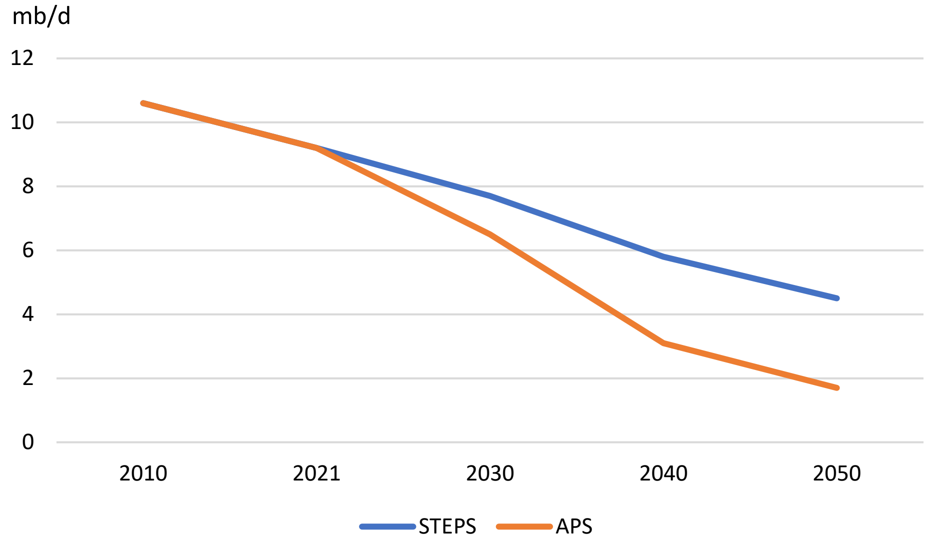


Figure 11 – Oil demand projections for the EU-27. STEPS: Stated Policies Scenario APS: Announced Pledges Scenario. (IEA, 2022)

3. Path to Net-Zero Emissions

Thomas Schlager, MSc

Dr.-Ing. Rafael E. Hincapie

Decarbonization of the Austrian energy system

Around 80 million tons of greenhouse gases are emitted in Austria every year, which is more than when climate efforts started around 30 years ago. In order to achieve climate neutrality in 2040, these emissions must be avoided or neutralized over the next 17 years.

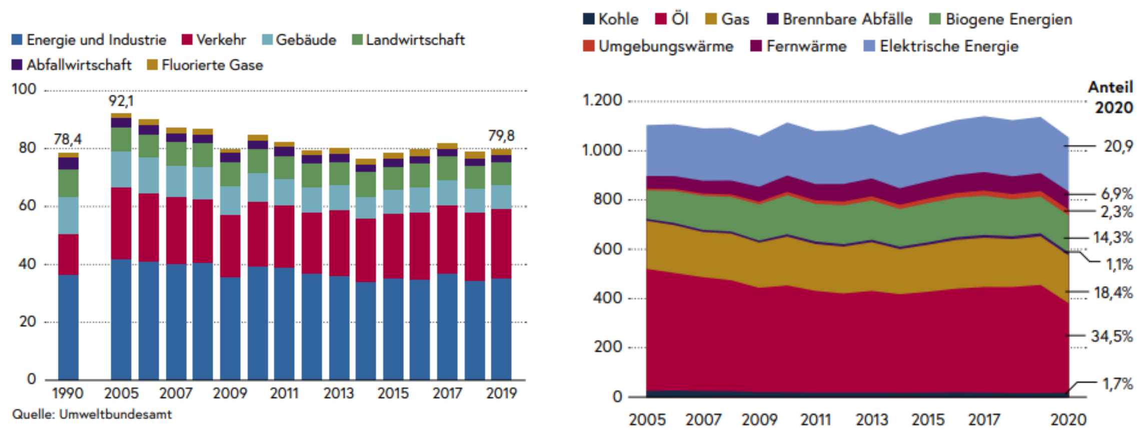


Figure 12 Left: Total greenhouse gas emissions by originator in million tons of CO2 equivalent; Right: Final energy consumption by energy source in petajoules 2005-2020 (BMK, Energie in Österreich 2021)

The decarbonization of the energy system is essential for achieving Austria's climate neutrality, as around 75% of greenhouse gases are energy related.

The transformation path towards full decarbonization in 2040 is a formidable challenge. The existing energy system will require profound and short-term changes, leading to transient effects and additional costs over many years. In any case, the transformation path towards a 100% decarbonized and optimized energy system requires the massive expansion and conversion of all available renewable energy sources and the establishment of efficient conversion, storage and end-use technologies.

A decarbonized Austrian energy system is possible through the:

1.) economical and efficient use of energy
2.) massive expansion of renewables
3.) removal of regulatory hurdles, especially in the area of renewable gases
4.) efficient use and sector coupling of the existing infrastructure

The oil and gas sector can play a leading role in the decarbonization of the energy system. The energy production processes will change from fossil-based energy to renewable energy, bio fuels, or renewable fuels of non-biological resource. Hard to abate CO2 emissions could be separated and reused. Renewable fuels and gases could be used in existing infrastructure, like refineries, grids and powerplants, ensuring the needed flexibility and long-term energy storage capacity needed for a safe and secure energy supply.

Current energy system in Austria

Fossil fuels, especially oil and gas, still dominate final energy consumption, even if the share of renewable energy is slowly increasing.

The Renewable Expansion Act (Erneuerbaren-Ausbau-Gesetz, abbr. EAG) defines two key energy targets for 2030: on the one hand, 100% electricity from renewable energy sources on a national balance (in 2019 the share was around 75%, which corresponds to an increase of a good 12 percentage points since 2005). With an expected further slight increase in total electricity consumption, this makes it necessary to expand renewable electricity generation by 27 TWh by 2030. In 2023, the national energy and climate plan (NEKP) even stated the necessity to increase yearly electricity generation from renewable sources by 34 TWh to enable reaching the energy targets for 2030. On the other hand, the feeding of 5 TWh of renewable gas into the gas network. Both goals require additional political measures.

Around 84% of the biogas produced in Austria is currently used to generate electricity and heat, the remaining 16% goes directly to final energy consumption, where 83% of it is used in industry. Biogas can also be used as an energy source for motor vehicles, although the quantities here are still relatively small. However, biogas can also be fed into the natural gas grid after appropriate gas treatment and purification. In 2020, 138 GWh of biogenic gases were fed into the grid, which after years of sharply increasing volumes, as in 2019, corresponds to a further decrease of almost 10%. The feed-in of renewable gases – currently almost exclusively biomethane – is to be greatly expanded and reach around 5 TWh in 2030.

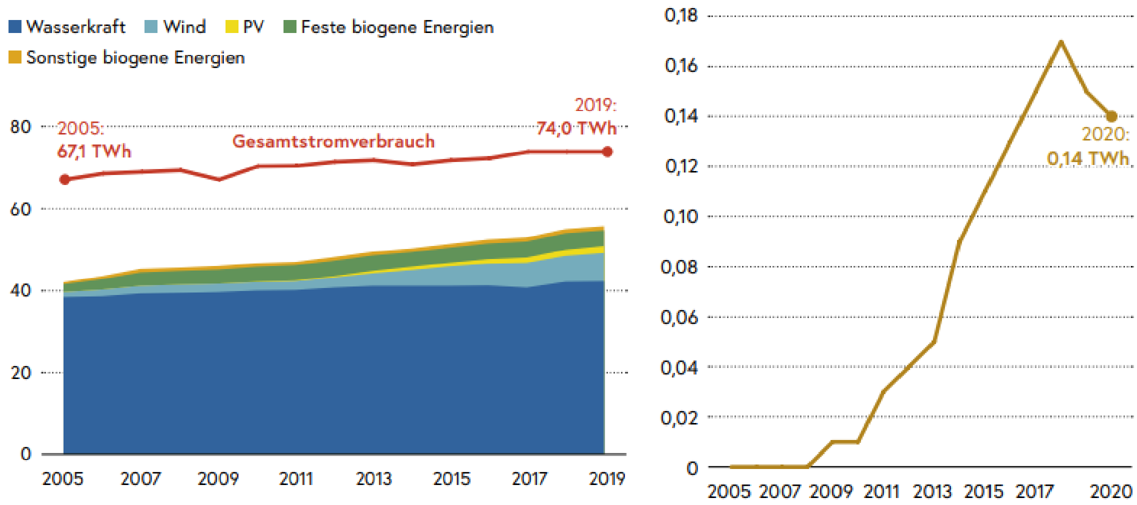


Figure 13 Renewable electricity 2005-2019 on the left and feed-in of renewable gases 2005-2020 on the right, in TWh (BMK, Energie in Österreich 2021).

An example of a decarbonized Austrian energy system

In the study " One100 – Österreichs Nachhaltiges Energiesystem – 100% dekarbonisiert" in autumn 2019, 12 Austrian energy companies together with Wagner, Elblinger and company developed a vision for an economically optimized, completely decarbonized energy system in Austria. The figure below provides an overview of energy generation, storage and use.

The following measures are proposed for the implementation of decarbonization:

- **Energy saving and efficiency increase:** Decrease in primary energy demand by 31% through efficiency measures, especially in the area of space heating and the use of efficient end-use technologies.

- **Expansion of renewables:** Oil, natural gas and coal are replaced by CO2-neutral primary energy from mainly domestic sources: 123 TWh from hydro, wind and solar power, 91 TWh from biomass and 10 TWh from energy imports, mainly for green liquid fuels.

- **Energy conversion and storage:** Primary energy has to undergo conversion and storage processes to a significant extent. The most important conversion steps serve to generate 81 TWh of renewable gases. Biomethane and hydrogen, together with renewable electricity, will be the core elements in the optimized energy system and make a significant contribution to decarbonization. The majority of the biomass used for energy is obtained from biogas and wood gas for the production of biomethane.

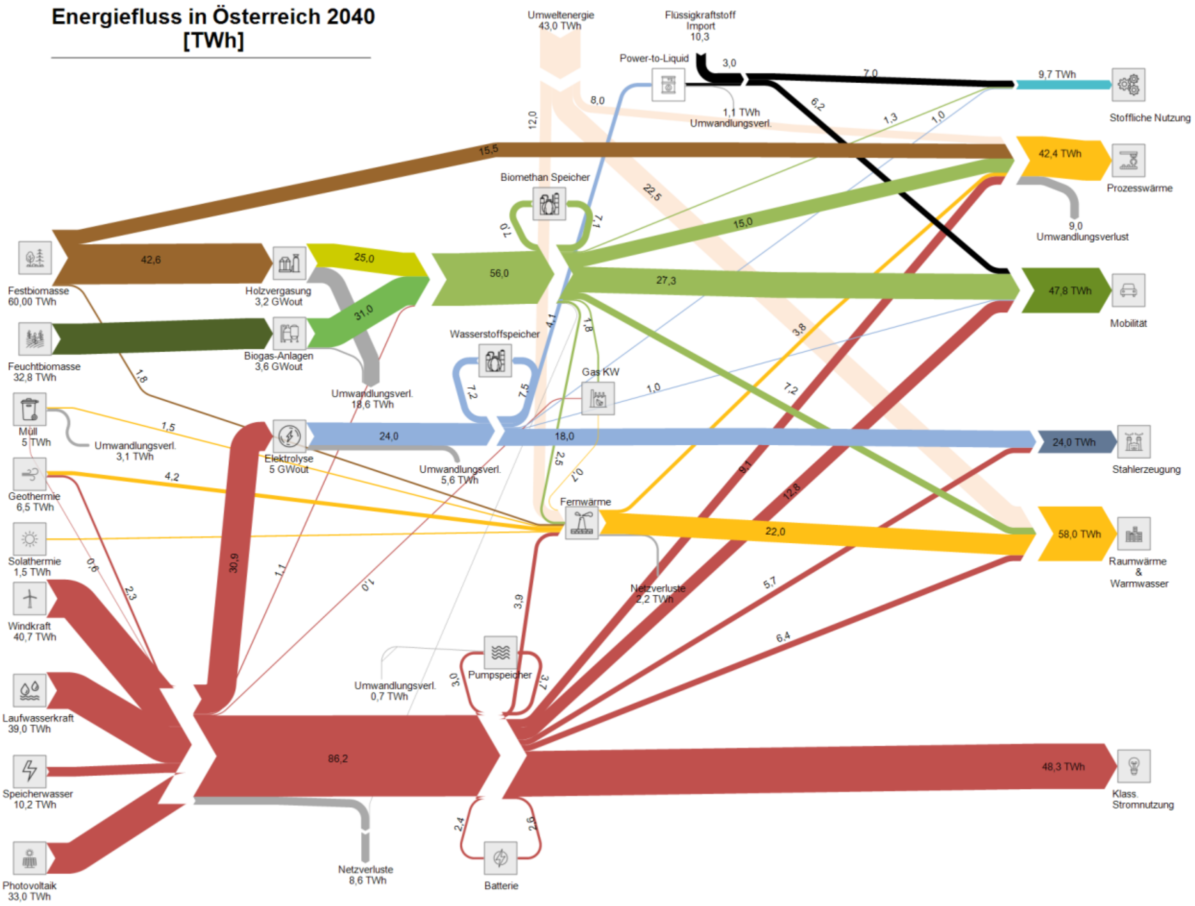


Figure 14 Overview ONE 100 energy system (ONE100 - AGGM - Austrian Gas Grid Management AG, no date)

Decarbonisation of Austria's energy system by 2040 is not possible without the oil and gas sector. Due to the electrification of the heating and transport sector, the electrical grid faces major challenges. In addition to grid expansion, innovative solutions such as smart grid applications, demand side management and new tariff and market models will be needed to master these challenges. For the long-term storage of energy in sufficient capacity, the use of renewable gases and renewable fuels will be unavoidable. Especially in industry and mobility, there are applications and processes that require the use of renewable gases and renewable fuels. With the production, purification, transport and distribution of renewable gases and renewable fuels, the oil and gas industry will play a key role in decarbonisation.

Oil and Gas Sector in Austria

Austrian oil and Gas companies are adopting their strategies to adapt to the changing environment.

OMV published the target of reaching net-zero GHG emission in its operations (Scope 1, 2, and 3) by 2050 or even sooner in its “OMV Strategy 2030” (OMV, 2022). OMV envisions to transform itself into a sustainable fuels, chemicals, and materials company with focus on circular economy. The Refining & Marketing division will focus on sustainable fuels, feedstock and mobility solutions. The production of oil and gas will be reduced by around 20% by 2030. By 2050, OMV plans to cease oil and gas production for energy use. The Exploration &

Production division will focus on geothermal energy and carbon capture and storage (CCS) solutions, “leveraging existing assets and capabilities and contribute to a more sustainable society”.

OMV is already producing SAFs in its refinery in Schwechat, where used cooking oil is used as feedstock. OMV plans to scale up to production of SAFs from 2 000 tons up to 700 000 tons per year by 2030 (OMV, 2022b).

OMV searches for geothermal energy in the Vienna basin, a geological area well known to the company. OMV aims at producing 9 TWh of energy from geothermal sources by 2030 (OMV, 2022c). First projects were already started. In Austria the company is conducting a production test to analyze the potential in the Vienna Basin. In Germany OMV contributes to a geothermal exploration project.

The production of geothermal energy requires several skill areas that are readily available in oil and gas companies. This includes geology, geophysics, petrophysics, reservoir engineering, and production engineering. Such companies have in general a rich portfolio of seismic and drilling data and the required geological expertise to explore geothermal potential. Additionally, they are skilled in drilling and have the required equipment and crews.

RAG aims at using only climate-neutral fuels for operating its facilities by 2040. This shall be reached by using its currently operated areas for the production of renewable energy. Existing well-sites will be upgraded with photovoltaic with the aim of produce 60 GWh of electricity. This first initiative shall provide 10% of RAG’s own-consumption in a climate-neutral way (RAG, 2022).

RAG consider its large-volume energy storage systems as an essential cornerstone for tomorrow's renewable energy supply and the basis for the further development of new energy technologies.

The company is involved in several research projects, where options for large-scale hydrogen storage are developed. For example, in the project “Underground Sun Storage 2030” hydrogen is produced from solar power and stored in underground gas storages to demonstrate such technologies under realistic small-scale conditions. RAG also leads the research project “Carbon – Cycle Economy Demonstration Project (C-CED)”, where different CCU technologies are combined. The objective is to convert the separated CO2 into sustainable methane, which will be used in a circular carbon economy.

4. Energy Efficiency and Decarbonization Technologies

Bojan Pejić, MSc

Dipl.-Ing. Magdalena Teufner – Kabas, MSc

Thomas Schlager, MSc

Adaptation of existing infrastructure for power generation

Gaseous fuels are used for 20% of the EU electricity production, and 39% of heat production (European Commission, 2021). When used for power generation, gaseous fuels are burned either in gas turbines, gas furnaces or gas fired boilers.

A combined-cycle power plant typically uses a gas turbine to drive an electrical generator and recovers waste heat from the turbine exhaust to generate steam. The steam from waste heat is run through a steam turbine to provide supplemental electricity. The overall electrical efficiency of a combined-cycle power plant operated on natural gas in full-condensing mode at full load is typically in the range of 50–60% with newest gas turbines breaking the 60% mark substantially. Nevertheless, this means that approximately 40% of the gas heat input is not converted into usable energy. Moreover, such power plants emit over 320 g of CO2 per produced kWh of electrical energy, which is above the 270 g/kWh threshold set by the European Commission in the Complementary Delegated Act and are therefore not covered by the EU taxonomy.

Waste heat utilization: Industrial processes and district heating systems

One of the simplest ways to increase overall efficiency when planning a new gas fired power plant is to utilize generated steam not only for production of electrical energy, but also heat.

When planning the location of a new gas fired power plant, one option to increase process efficiency is to install the power plant close to a steam intensive industrial facility and consider steam extraction points at required pressure and temperature levels when designing the steam turbine. In that way, the generated steam is used to generate electrical energy by expanding within the steam turbine until it reaches parameters required for industrial processes. After extraction, it is applied as a heat source in industry.

Another possibility to improve the fuel utilization level is to use the process heat for district heating purposes. In that way, the power plant does not only produce electrical energy, but also provides thermal energy, which significantly improves total process efficiency. Depending on the district heating system's demand and capacity, the efficiency of the combined heat and power plants can significantly surpass 90%, which drops the CO2 emission levels below 230 g per produced kWh of useful energy. This means that combined heat and power plants (which is an already existing and well-established technology) are considered as acceptable technologies by the European Commission without any further adaptations and are covered by EU taxonomy if operated at loads which keep the CO2 emissions below the threshold.

As seen in the Figure 12, only approx. 20% of the Austrian households use district heating as a primary heat source, with the percentage varying from less than then 10% in Burgenland and Vorarlberg up to approximately 30% in the city of Vienna. At the same time, over 50% of the Austrian households use gas and oil heat boilers or wood burning stoves as a heat source. Apart from the fact that the average CO2 emission of oil boilers is higher when compared to gas boilers and wood burning stoves, all those decentralized heat sources have as a result an additional risk factor in the household due to the flammability and/or explosivity of the utilized fuels. Additional disadvantage of such centralized heat sources is space within household required for installation.

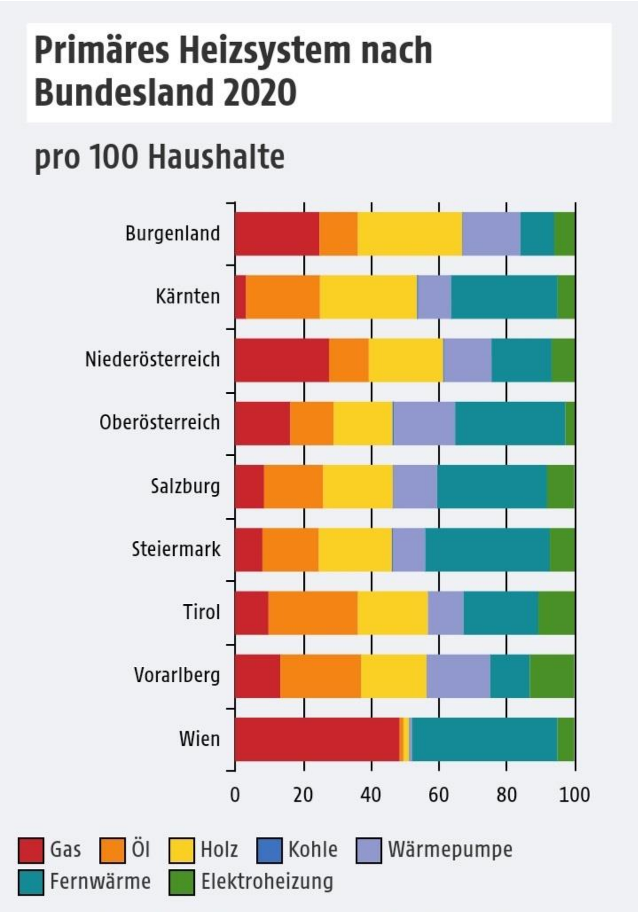


Figure 15 share of primary heat sources in households in Austria in year 2020 (Statistik Austria/ Klimadashboard)

Utilization of gas turbine generators to stabilize the grid

The district heating system heat demand varies throughout the year, reaching the peak in winter months, and usually declines or is not present at all in the summertime. At the same time, share of electricity produced from renewable energy sources reaches its peak in summer months due to higher production rates of photovoltaic power stations, which implies that power generation capacity of gas fired combined heat and power plants can be partially or completely substituted in warmer months by the climate neutral sources.

However, renewable generators such as photovoltaic (PV) and wind power have several disadvantages compared to fossil energy sources. Both systems are low-output and intermittent, with generators coming on- and off-line as the meteorological conditions vary. With increase of the portion of renewables in the power generation market, short circuit power capacity in the grid is reduced and there are frequent voltage and frequency swings. Furthermore, some regions are more PV-dominant and some are more wind-dominant which causes an increase in the power transport from one region to the other depending on the weather conditions and causes additional stress on the transmission networks. This has a major negative impact on the dynamics, resilience and stability of the grid.

One way to deal with the above-mentioned drawbacks of renewable generators is to use generator turbines of fossil fuel power plants for grid stabilization purposes. In periods when there is a higher availability of the renewable energy sources and the demand for district heating is low (e.g. summertime), combined heat and power plants could be shut down or operate on reduced load. In that case, generators of the non-operating turbines could be physically decoupled from the turbine and connected to the network through a transformer. This action would convert them into so called “synchronous condensers”. After the generator is synchronized with the network, it provides the necessary short-circuit power through the inertia of its rotating mass and provides or absorbs reactive power through or out of the network which results in a more stable transmission network able to withstand voltage and frequency swings caused by intermittent energy production by renewable sources.

Any turbine generator can be converted into a synchronous condenser. In the light of the current coal phase-out policies, such conversion can be a method of repurposing and revitalization of generators of the existing coal power plants which are approaching the end of their life cycle by reusing them to add required inertia and stabilize grid systems dominated by renewables.

Integration of gas fired plants into hybrid systems

As both fossil fueled power plants and renewable energy sources provide different benefits at the cost of their discussed drawbacks, future energy systems will likely integrate various technologies into hybrid systems.

Hybrid power plants contain two or more modes of power generation, usually using renewable energy sources such as solar or wind, accompanied by a fossil fueled generator and/or storage system (e.g. battery or a fuel cell). Fossil fuels can be in the future substituted by low-carbon and renewable fuels, ensuring that all elements of a hybrid power plant are in line with the net-zero targets.

By taking advantage of developments in system communication, data gathering, exchange and utilization (e.g. by taking into account the weather forecast or energy consumption profiles), each element of a hybrid power plant can be operated when possible and economically viable. In that way power efficiency is increased and greater balance in energy supply is ensured.

Carbon capture and Utilization

One way to prevent remaining CO_2 being released into the atmosphere is to couple the exhaust systems of the power generation units with carbon capture facilities which separate CO_2 from the remaining exhaust gas elements, treat it and prepare for further storage or reuse.

The International Energy Agency (IEA, 2018) sees Carbon Capture and Utilization as building block for still reaching the climate goals. In Figure 13 from the World Energy Outlook 2018, Carbon Capture and Utilization/Storage is an important technology to reach goals from the Sustainable Development Scenario.

Utilizing CO_2 from regional sources to produce a value-added product leads to (1) independence from fossil raw materials (2) local value generation (3) is climate-friendly and (4) is a scalable technology. With biobased CO_2 not only zero-emissions, but net-negative-emissions through binding CO_2 are possible.

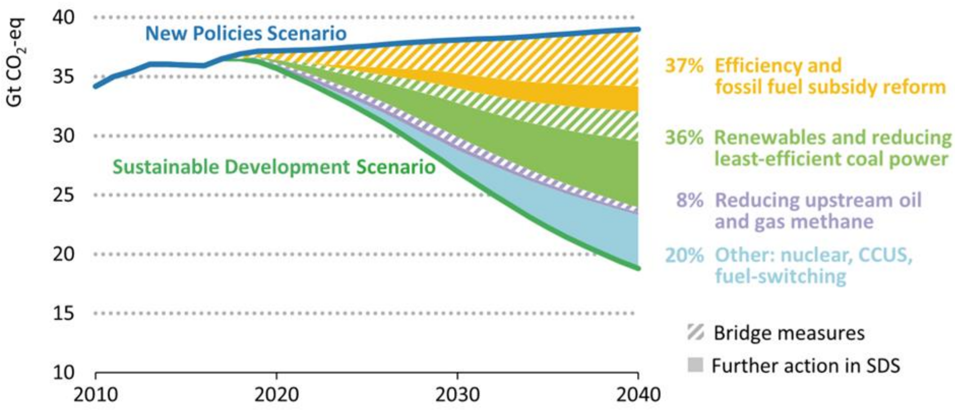


Figure 16 Scenarios to cut CO2 emissions (IEA, 2018)

Although capturing and storage or capturing and reuse of CO_2 will not be able to prevent climate change on its own, they are supporting measurements which indirectly lead to a reduction of greenhouse gas emissions (Fischedick et al., 2015). Furthermore, capturing and reuse of CO_2 can open new economic markets.

CO_2 as a Resource

In 2021, Global CO2 emissions from energy combustion and industrial processes made up 36.3 Gt and reach their highest level (IEA, 2021). With 46 % the power and industry sector, dominate global GHG emissions (IPCC, 2014). Those emissions mainly result from the oxidation of carbon when fossil fuels are burned.

CO2 emissions are responsible for 89 % of all greenhouse gas emissions **from energy combustion and industrial** processes in 2021. 0.7 % of those GHG emissions are CO2 emissions due to gas flaring. Fugitive and combustion related CH4 emissions account for 10 % and nitrous oxide made up 0.7% (IEA, 2021). Carbon dioxide also result by using fossil fuel as a feedstock for petrochemical processes (Chauvel and Lefebvre, 1989; Christensen and Primdahl, 1994); by using carbon as a reducing agent in the production of metals from ores (IEA GHG, 2000); during the thermal decomposition (calcination) for cement or lime production (IEA GHG, 2008); and the fermentation of biomass (e.g. alcohol from sugar, biogas). In some instance these emissions achieve higher CO2 concentrations in the off-gas compared to combustion processes. However, the use of biomass as a fuel is very limited to certain areas like Scandinavia and Brazil (Möllersten et al., 2003).

CO2 emissions are produced in different scales and sources. **Large stationary sources** are generated by burning fossil fuels in boilers and furnaces which will be emitted from exhaust stacks. In contrast to that, mobile sources from transportation or small stationary emission which result from small heating boiler, emit small fractions of carbon dioxide. Large CO2 sources offer the opportunity to **separate CO_2 in well-equipped capture plants** to achieve high-purity and high throughput (Simmonds et al., 2003). With great volumes, separation and conversion technologies can improve from economy of scales.

CO2 contributes 85% of the total **greenhouse gas emissions in Austria** (Anderl et al., 2019b). To fulfill the reduction goal from the Kyoto protocol, Austria need to reduce 5.2% of their greenhouse gas (GHG) compared to 1990. 2005 was the year with the highest CO_2 emissions. Since then, the emissions were reduced (Anderl et al., 2019a).

Important emitters are energy and industry (45 %), transport (29 %), buildings (10 %) and agriculture (10 %). In Austria **industrial processes** are responsible for 26 million tons of GHG before **transportation sector** with 24 million tons and **energy production** with 6 million tons of GHG. Emissions due to oil refinery made 2.75 million tons of greenhouse gases while steel processing made 12.77 million tons (Anderl et al., 2019a).

From the regional perspective Upper Austria is the highest emitter of greenhouse gases with 29% of the total emissions in Austria. Lower Austria and Styria are following with 23 and 17 percent. Caloric power plants and industries like the steel processing in Linz and the oil refinery in Schwechat are mainly contributing to the regional breakdown (Anderl et al., 2019a). Austria's industries are punctual emissions spots which can be perfectly used as a CO_2 source for chemical conversion.

Products from CO_2

Various CO_2 utilizing pathways can be found in many different industrial branches e.g. **chemical** industry, **pharmaceutical** industry, **manufacturing** and construction uses as well as **food** and **beverage** industry. In some forms CO_2 has already been used for decades e.g. as an extracting agent in the decaffeination process of coffee and tea (Fischedick et al., 2015).

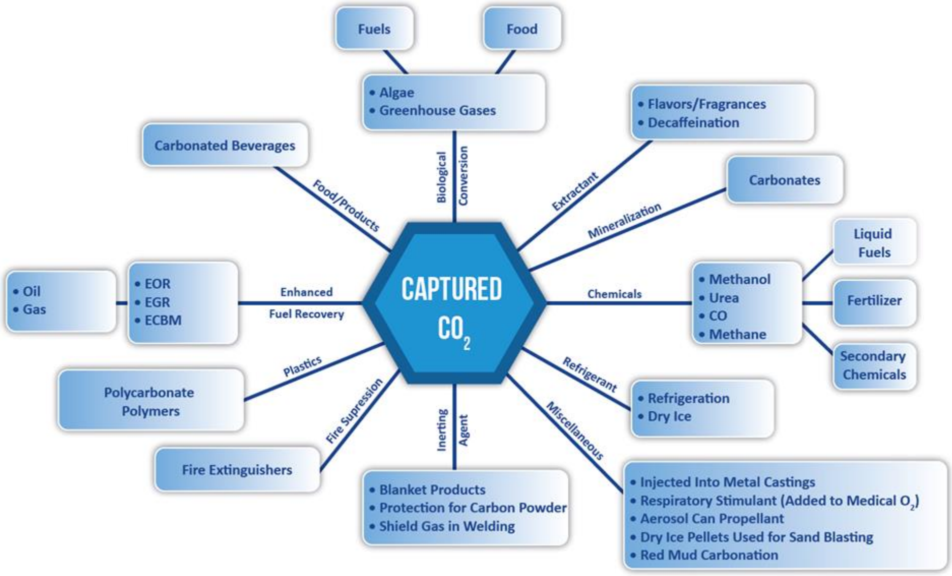


Figure 17 Products that could be obtained from captured CO2 (Smart Specialisation Plattform, n.d.)

Physical CO_2 utilization: Physical applications use CO_2 due to its special physical properties either pure or within multi-component systems. These industrial fields have a large demand for CO_2 but cannot be seen as a sink of the greenhouse gas as it is released comparably fast after the utilization. Anyhow, the utilization of CO_2 from biological sources can reduce the necessity for industrial production of CO_2. Therefore, future CO_2 emissions are reduced indirectly. Fields of physical CO_2 utilization (Fischedick et al., 2015):

- Enhanced Hydrocarbon Recovery: Supercritical CO_2 can be injected into depleted oil wells to enhance the further recovery of oil and gas.
- Extraction: Supercritical CO_2 is a good solvent for non-polar substances and therefore a green alternative to organic solvents. Well established applications are for example the decaffeination of coffee and tea.
- Gaseous CO_2 is very well soluble in water and is used for the carbonation of beverages.
- Refrigerant: CO_2 has a high refrigerating capacity in liquid and solid state. Liquid CO_2 is used as a refrigerant in air-conditioning systems. Solid CO_2 ("Dry ice) can be applied to ensure a safe transport of frozen goods. Compared to conventional refrigerants, CO_2 possesses a lower global warming potential and there is no risk of fire or of hazardous degradation products.
- Inerting agent: Due to its chemical unreactive characteristics, CO_2 can be used for example as a protection gas for welding.
- Cleaning processes: Various CO_2 based procedures to clean textiles and components are known. They either use mechanical-physical effects or CO_2's potential as a solvent.
- Some procedures to manufacture particles and powders function using compressed CO_2. The best-known ones are Rapid Expansion of Supercritical Solutions (RESS), Precipitation with a Compressed Fluid Antisolvent (PCA) and Particles from Gas Saturated Solutions (PGSS)
- CO_2 acts as a fire-extinguishing agent by suppressing oxygen around flames.
- To stimulate respiration, CO_2 is added to medical oxygen.
- Propellant in Aerosol cans or in the production of polymer foams
- Impregnation

Chemical CO_2 utilization: In the chemical field, CO_2 can be used as a feedstock for the production of further chemicals. As CO_2 is a non-polar, chemically unreactive gas persistent in the atmosphere under standard conditions, the molecule needs to be activated by the use of a catalyst or the adding of activation energy to allow successful conversion reactions. CO_2 utilization pathways of commercial interest are the following ones (Fischedick et al., 2015):

- Reduction of CO_2: The most important commercial products obtained by this process are methanol, dimethyl ether and methane.
- Conversion to organic carbonates: The annual production amount of the commercial linear and cyclic organic carbonates reaches from 400 kt to 1 Mt.
- Conversion to urea: The urea production represents the largest field of chemical CO_2 utilization. For the annual production of 146 Mt of urea (mostly for fertilizers), 107 Mt of CO_2 are needed (Wietschel et al., 2015).
- Conversion to salicylic acid: This process is another large-scale industrial utilization of CO_2. Salicylic acid plays an important role in the production of Aspirin® and is obtained from the Kolbe-Schmitt reaction.

These reactions are already running on an industrial level and considerable efforts are going into the prospective area of further chemical conversions of CO_2.

Shift from natural gas to hydrogen and renewable gas

Although gas fired power plants cause significantly lower CO_2 emissions compared to coal and oil-fired plants, on the path towards a net-zero future those emissions levels are not acceptable. To meet the internationally set decarbonization targets, all fossil fuels need to be phased out. This target can be achieved gradually by blending fossil fuels with low-carbon and renewable gases until the point where fossil fuels are not blended to the mix at all anymore.

Low-carbon and renewable gases come in various forms: hydrogen; hydrogen derivatives such as e-methanol, e-methane, and e-ammonia; and biofuels like bioethanol, biogas and biodiesel. They are typically derived from water and renewable energy, natural gas with carbon capture and storage, or organic matter, such as plants, timber, and agricultural and food waste.

The European Commission expects that, in accordance with the policy scenarios that underpin the “Fit for 55” initiative, biogas and biomethane, renewable and low-carbon hydrogen and synthetic fuels will gradually replace fossil natural gases and represent very significant shares of the gaseous fuels in the energy mix towards 2050 (European Commission, 2021).

Green hydrogen can be produced by means of electrolysis using renewable energy and water. Due to the water availability and its high-cost reduction potential, hydrogen is the main candidate to be the main future fuel for gas turbines. Modern gas turbines can be operated with a mix of hydrogen and natural gas from 5% to 100% and major gas turbine produces have committed to furtherly develop gas turbines able to burn 100% hydrogen.

A derivative of hydrogen, e-ammonia, doesn’t emit carbon dioxide when burned either and could be used directly to fuel gas turbines, however it does emit high NOx levels and the fuel’s toxicity required cautious handling, so research of the fuel’s utilization is in very early stage and commercial application of e-ammonia in gas turbines is not expected in the near future. However, e-ammonia is easily transported and once distributed, it can be ‘cracked’ to produce hydrogen.

E-methanol is easy to synthesis, using a sustainable form of CO_2. With increasing application of carbon capturing technologies, it is expected that it will be produced in large quantities. E-methanol can be easily burned in gas turbines requiring minimal equipment and facility adjustments.

Biofuels can be produced via a closed-loop circular carbon process and are therefore considered renewable. Depending on how it's produced, the composition of biogas, for instance, can be very close to natural gas and can be easily adopted in existing gas turbines and infrastructure. Examples of biofuels include: hydrotreated vegetable oil (HVO), fatty acid methyl ester (FAME), ethanol and dimethyl ether.

5. Transition of Wholesale Energy Markets

Dipl.-Ing. Jasmin Mensik

Status Quo

The EU Commission’s goals for a climate-neutral Europe have a special emphasis on the integration of hydrogen and renewable gas in the energy sector. Large-scale deployment of clean hydrogen at a fast pace is key for the EU to achieve the emission reduction goals of 55% by 2030. A great number of Member States have developed plans and implemented actions for clean hydrogen in their national strategies. Bringing the hydrogen development to the next level, requires an enabling regulatory framework, a lot of investment, sustained research and innovation of technologies as well as for new market solutions, the establishment of the necessary infrastructure and the establishment of new markets (European Commission, 2020).

Looking at the upstream level, the main interplay between a future hydrogen wholesale market and electricity and natural gas wholesale markets is that hydrogen production is a form of consumption of natural gas (reforming) and electricity (electrolysis). Looking at the midstream level, the main interaction between hydrogen as well as for other renewable gas with natural gas markets can be found when looking at blending as well as the shared usage of existing gas infrastructure (e.g. storage, transport pipelines).

The significant role for global economies, the imperative of this sector for power and heat supply as well as financial concerns regarding energy, are shaping energy markets with high complexity. New dynamics emerge on a continual basis, due to the need for solutions and innovations addressing energy transition and the fast growing of energy markets (European Union Agency for the Cooperation of Energy Regulators, 2020).

Electricity and natural gas wholesale markets are affected by several dynamics. The following delineation is not exhaustive but provides a picture of some key-dynamics. Since natural gas serves as primary energy carrier to produce electricity, there is a given correlation between electricity and natural gas markets and prices. Both markets are affected by not only local developments but also global dynamics. To give an example, gas prices in Austria – a landlocked state - may rise due to a supply shortage regarding liquefied natural gas (LNG) which is transported via the sea route to other European markets. The interplay between local markets can be seen as third dynamic. This dynamic is even growing in the light of the European goal to foster an integrated EU-energy market (E-Control Austria für die Regulierung der Elektrizitäts- und Erdgaswirtschaft, 2021).

Crucial for the establishment of a functioning wholesale market is, that market participants have trust in transparency and integrity of this market. Based on this, liquidity can arise which in the following ensures the functioning of an efficient and sustainable market. The European Union Agency for the Cooperation of Energy Regulators (ACER) deems it sufficient to establish an effective monitoring regime which could be integrated in the existing market surveillance approach of the gas and electricity wholesale market (European Union Agency for the Cooperation of Energy Regulators, 2020).

How to conclude an energy wholesale contract?

A considerable share of electricity and natural gas wholesale contracts are concluded over-the-counter (OTC) either bilaterally e.g. between generators and suppliers or via a broker as intermediary party or a dedicated broker platform. Another way is to trade electricity or natural gas on an exchange, where a variety of standardised products are offered which mainly can be differentiated by delivery dates (e.g. day-ahead, month-ahead, year-ahead, etc.) (E-Control Austria für die Regulierung der Elektrizitäts- und Erdgaswirtschaft, no date).

Exchange
Standardized Products

- **Futures Market**
  - Month-Ahead
  - Quarter-Ahead
  - Year-Ahead
  - etc.
- **Spot Market**
  - Day-Ahead
  - Intraday/ Rest-of-Day
  - etc.

Bilateral/Over-The-Counter
Standardized And Non-Standardized Products

- **Standardized Products:** Have similiar characteristics like exchange products.
- **Non-Standardized Products**: Multifaceted contract specifications possible, depending on what the counterparties of a contract agree.

Figure 18 Trading On European Energy Markets An Overview (E-Control Austria für die Regulierung der Elektrizitäts- und Erdgaswirtschaft, no date)

Benefits of trading on an exchange are on the one hand that a clearing house takes care on the clearing conditions and on the other hand the reduced counterparty risk. The value of this benefit is especially visible during periods of high price volatility and market uncertainty like it can be assessed since 2021, where an increased number of market participants started trading on an exchange like the European Energy Exchange (EEX), instead of concluding their contracts over-the-counter (Edwardes-Evans, 2022).

Policy & Regulatory Framework

The economy for renewable gases and hydrogen is still in its infancy. Nevertheless, is the development of conditions for the handling and trading a pre-condition to unfold their potential in light of Europe's decarbonisation objectives. The establishment of a market for hydrogen and renewable gas includes a variety of different policies and regulatory rules. The following section contains a non-exhaustive enumeration of some key parts.

Hydrogen and Decarbonised Gas Market Package – revising Gas Directive and Gas Regulation to allow for hydrogen's role in the gas market

The Commission's proposals were released on 15th December 2021 and aim to ease the transition from fossil natural gas to low-carbon and renewable gas – specifically hydrogen and biomethane. One major part is to create a prosperous environment for investment, enable infrastructure development and to establish international trade for hydrogen. The proposed set of rules is envisaged to become applicable in two phases, before and after 2030. The package includes the proposal to condense the national infrastructure development plans for electricity, gas and hydrogen into one common plan, which in addition is strongly based on the European approach. Another point is to facilitate access of renewable and low-carbon gases to the existing gas infrastructure. Consumer protection and empowerment are also part

of this set of rules. Furthermore, the resilience of the gas system shall be improved. The package additionally addresses the establishment of a new European framework to measure, report and verify methane emissions.
Apart from this, the package provides legal clarity on the definitions of blue and green hydrogen within the EU's energy regulatory framework for the climate transition. Those are in line with the proposed amendment of the Renewable Energies Directive II (RED II).

- Blue: The scope of low-carbon gases encompasses a production of at least 70% less greenhouse gas emissions than fossil natural gas, taking into account their full lifecycle.
- Green: Renewable gases are produced from biomass including biomethane, as well as hydrogen produced from renewable sources (European Commission, 2021).

A number of definitions and standards although, are still not legally defined and will be part of the European Commission's future timeline for the establishment of a hydrogen market. This means, that the market won't be able to base e.g. investment decisions on this missing piece of information for a while (Barnes, 2022).

The European Hydrogen Strategy

The European Hydrogen strategy envisages the establishment of a new hydrogen market in three steps. During the first phase, small local markets including micro and island grids, will emerge most likely next to existing demand centres e.g., steel plants or chemical complexes. Infrastructure will at this stage still be limited but planning of an established infrastructure for mid- and long-term transmission should begin. The strategic European objective to decarbonise the existing hydrogen production envisages the installation of at least 6 GW electrolyser capacity feed by renewable power. Furthermore, the focus will be laid on the establishment of the necessary regulatory framework, for a well-functioning hydrogen market and different approaches to incentivise demand and supply. Part of this is also to close the cost gap between renewable or low-carbon hydrogen solutions and fossil-based technologies. In the second phase, between 2025 and 2030, it is expected that, renewable hydrogen becomes gradually cost-competitive with conventional ways to produce hydrogen. By 2030 at least 40 GW of renewable hydrogen production capacity shall be installed. The role of renewable hydrogen for daily or seasonal storage will grow during this phase. Trading on international markets can be developed continuously. A competitive, liquid and commodity-based hydrogen market, allowing barrier-free cross-border trade, should be established by 2030. The last phase, between 2030 and 2050 is characterized by a large-scale deployment of renewable hydrogen in sectors which are difficult to decarbonise. This includes synthetic fuels but also sustainable biogas which could also play a role (European Commission, 2020).

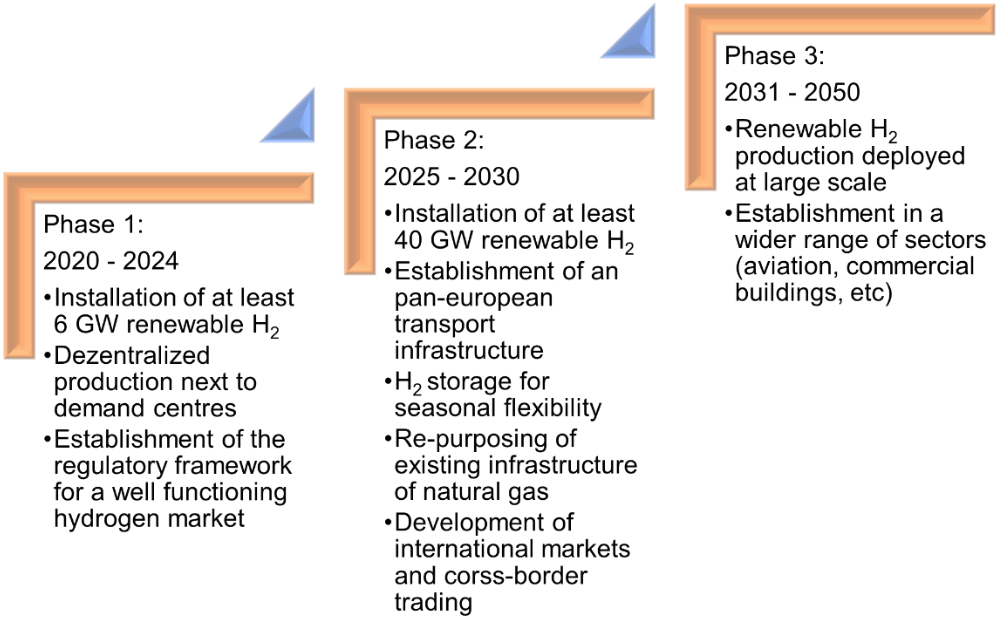


Figure 19 European Hydrogen Strategy Roadmap (European Commission, 2020)

The Commissions REPowerEU plan, released on 18th May 2022, highlighted hydrogen as an important part of the solution, especially for hard-to-decarbonise sectors. The plan envisages an even faster acceleration of supply and demand than outlined in the Hydrogen Strategy.

The new plan proposes the achievement of 35 bcm of annual bio-methane production by 2030. It furthermore foresees a target of 10 million tonnes of domestic production of renewable hydrogen and 10 million tonnes of imports by 2030 (European Commission, 2022).

Energy Wholesale Market Surveillance – REMIT

Obligations and prohibitions for market participants in the electricity and natural gas wholesale markets in Europe are outlined in Regulation (EU) 1227/2011 on wholesale energy market integrity and transparency (REMIT). REMIT entered into force in 2011 to support open competition and a level playing field in the European wholesale energy markets. The overall goal is, to increased market transparency and integrity, by prohibiting any trading based on inside information and market manipulation, to protect the interests of companies as well as of customers. To detect such practices, the Agency for the Cooperation of Energy Regulators (ACER) manages the Europe-wide market monitoring which is complemented by the investigative powers of national regulatory authorities. A main element to enable market monitoring, comprises data reporting and publication obligations which cover orders and transactions related to energy wholesale products, fundamental data and inside information. Furthermore, market participants are obliged to obtain an ACER code by carrying out the REMIT registration, to ensure the unique identification of all market participants. Any engagement in, as well as any attempt to engage in, market manipulation or inside trading on wholesale energy markets is prohibited (European Parliament and Council, 2011).
ACER envisages a full-scale application of REMIT to hydrogen, including the reporting of hydrogen wholesale orders and transactions, similarly to natural gas and electricity. Considering the anticipated high interconnection between a hydrogen market with electricity and gas markets, an integrated approach to monitoring as well as surveillance seem to be the most effective and the most cost-efficient way (European Union Agency for the Cooperation of Energy Regulators, 2020).

Possibilities/ Developments

Historically, there have been peaks of interest in hydrogen, though it did not take off. In present times, new possibilities are arising due to the urgency to meet energy transition goals, technological developments, and the rapid cost decline of renewable energy production.

Many indicators signal that we are now close to a turning point. Every week new investment plans are announced, often addressing capacities at gigawatt level. A holistic approach, addressing the whole value chain, is precondition to establish this new wholesale market. Necessary is not only scaling up the supply side and boosting the demand side, as well as the establishment of the necessary infrastructure to connect supply and demand. In addition, a clear and market-compatible set of rules and a supportive regulatory framework are key to foster liquid markets and competition (European Commission, 2020).

Transparency and market trust:
Knowing the carbon footprint to meet greenhouse gas reduction targets is important from an investment point of view, but also for customers to serve as a base for decision making (Barnes, 2022). Subsequently, key for the establishment of a wholesale market for renewable gas and hydrogen, are transparency and trust. Thereby, a detailed terminology and EU-wide criteria to certify the Guarantee of Origin (GO) of a product are necessary. A Guarantee of Origin (GO) as an electronic document that provides information regarding the origin of a product, enables traceability and improves transparency for all market players (European Commission, 2020; Grexel Systems ltd. – part of eex group, 2020).

A particular challenge is to establish a common classification scheme, applicable at international level, which takes into account sustainability criteria across the whole lifecycle allowing traceability of all attributes (IPHE Hydrogen Product ion Analysis Task Force, 2021). Design and policy goals of hydrogen certification will differ from country to country. To name but a few, the objectives will be influenced by product preferences (e.g. renewable or low-carbon), government support, whether the region is focussed on import or export, and also depend on climate targets (Barnes, 2022). In this context, it is especially important that the certificates are internationally transferrable, which allow also trades beyond Europe (IPHE Hydrogen Product ion Analysis Task Force, 2021; EEX & H2Global Stiftung, 2022).

According to the European Hydrogen Strategy, the GO-system could be based on the methodologies of the already existing CertifHy system, which was initiated back in 2014 upon the request of the European Commission (European Commission, 2020). Although the current setup provides only limited value since additional system adjustments would be necessary to enable acknowledgement as proof that EU decarbonization targets are met.

Another important question is, what emissions will be included in the calculation of the footprint. The general system boundary is expected to be "well-to-gate", which includes the process from the raw material up until to the production process. "Well-to-wheel" would be another possible approach. There the system boundaries would take into account transport, distribution and end use in addition. Depending on what scope is chosen, the carbon footprint of the certificate changes. Another point for discussion is how carbon is tracked. There are two principles, either already in place or proposed to be used. First there is the "book-and-claim" principle, which provides no physical linkage between the hydrogen producer and the user. It would allow a fast market ramp-up but requires connection to the existing Emissions Trading system. An example is the current European Guarantees of Origin system for electricity. The second principle, the mass-balancing approach, foresees a direct physical linkage between hydrogen production and consumption. Due to that, no linkage to the

Emissions Trading system is necessary. This principle requires physical infrastructure to already exist or to be developed simultaneously. Blending of hydrogen, in the sense of putting hydrogen into the existing natural gas network, also follows the mass-balancing approach (Barnes, 2022).

The current idea of a European certification system aims at a mass-balancing approach, where the commodity together with the certificate is traded (Brandes, 2021).

In addition, there are registration systems like the AGCS Biomethane Register Austria which are developed on a national basis. Challenge here is to enable barrier free connection and transfer into European and international certification-systems (AGCS Gas Clearing & Settlement AG, 2021).

Transparency and reliable price information play an important role to build market trust. In addition, they contain the possibility to drive investment and price certainty for project developers in favour of renewable hydrogen. Due to that, price indices play a crucial role for the successful development of new wholesale markets. On the one hand, only cost-based indices, on the other hand indices, which include the production as well as the demand side, exist at the moment. A further difference is, which technology is included for the production of hydrogen e.g. electrolysis, steam reforming with and without CO_2 storage, etc.. In quarter one 2022, the European Energy Exchange (EEX) announced that they are working on a hydrogen index, which shall be based on price assessments by market participants (EEX & H2Global Stiftung, 2022).

Marketplaces, Trading and Prices

The ramp-up period of the European Hydrogen strategy envisages isolated hydrogen islands, where contracts are concluded bilaterally between producer and consumer in areas where players combine their hydrogen-related business activities. With a growing number of supply, demand as well as available transport infrastructure, more and more market players will arise. Complemented by infrastructure development, the growing number of production assets may lead to the occurrence of European production-hubs and gradually integrate in an European-wide network. Delivery points, where demand and supply naturally meet, are characterized by a high likelihood to result in a hub. Depending on the extension of transport infrastructure, these may become import-hubs as well. Depending on geographical conditions, transportation can happen via pipeline or off the line e.g., via ships or trucks. Depending on market structures, the way contracts are concluded could access a more open way of trading like via broker-platforms (OTC) or exchanges. These marketplaces connect a high number of different players on the supply as well as on the demand side. Liquidity is bundled and transparency as well as competition are improved. The wholesale market design could be mirroring the existing structure for natural gas markets (Trepte and Holler, 2021).

Traded Market	**Phase 1: 2020-2024**	**Phase 2: 2025–2030**	**Phase 3: 2030- 2050**
		Liquid Hub-Trading	Pacific/ Atlantic H_2 -Markets
Bilateral	H_2 -Islands	H_2 -Production hubs	
	Localised Market	National-/ EU-wide Market	Global Market

Figure 20 Potential Development Of A Hydrogen Market - From A Trading Perspective (Trepte and Holler, 2021)

Despite high levels of uncertainty, energy exchanges are already carrying out assessments and taking out first steps to create a marketplace for hydrogen or renewable gas. In March 2022, The European Energy Exchange (EEX) announced plans to develop a trading market particular for hydrogen (EEX & H2Global Stiftung, 2022). The Austrian market-operator Central European Gas Hub AG launched the CEGH GreenGas trading platform in quarter two of 2022. In a first phase the platform enables purchase or sale of biomethane with guarantees of origin (GOs) as well as of biomethane without GOs. In a second phase it will also enable for hydrogen trading. Contracts are either agreed directly between two counterparties or via an organised auction. The platform shall gradually be expanded to other market areas to allow cross-border trading (Central European Gas Hub AG CEGH, 2022).

Costs and prices in a future market will be influenced by the underlying production technology (renewable, low-carbon or fossil-based hydrogen, with or without carbon capture and storage, etc), the geographical region where it is produced (e.g. electricity-based production in regions where renewable electricity is available at low costs) as well as based on the sector specific regulatory rules and different influences applicable in the sector where it is finally used. For example, hydrogen prices applied in the heat sector will vary from the transport sector or from the industry sector as a result of sector-specific regulatory rules and different influences. The price for green hydrogen in case of blending is currently determined by the price of natural gas. Depending on the production method, it makes furthermore a difference (e.g. regarding fees) whether an electrolyser receives power from the grid or via direct link to a renewable power plant (European Commission, 2020; frontier economics, 2021).

Transportation, shipping and potential re-conversion costs will in addition play a role for commodity costs and prices.

Depending on market structures, two different pricing structures may be visible in less liquid markets. On the one hand the Hydrogen-to-power pricing in areas where hydrogen is produced predominantly power-based via electrolysers. And on the other hand, Hydrogen-to-gas pricing could be visible, in areas where hydrogen competes with natural gas or where hydrogen is produced based on natural gas (Trepte and Holler, 2021).

Conclusion – An Energy Industry Shows Itself With Colorful Facets

The decarbonization of Austria's energy system is a multi-layered and challenging task, which involves significant transformation in energy generation, consumption and policy. It is inevitable to reduce the use of fossil sources as the major cause of greenhouse gas emissions. To meet Paris Climate Goals it requires significant policy changes and investment to transition to a system based on renewable energy sources. To address this challenge, we have to act at multiple layers. Thinking of governments providing necessary policies and regulations that support the transition and businesses deciding to step into a sustainable direction by investing in renewables. But also individual members of our society are a vital part of the transition and can make changes by adapting their consumption habits and reducing energy demand (International Energy Agency, 2020; United Nations Development Programme, 2019).

CCUS technologies have the potential to reduce CO_2 emissions from the oil and gas sector, but there are limitations to their effectiveness. These limitations include availability of suitable storage locations, high implementation costs connected to CCUS technologies and the requirement of a large-scale deployment to achieve a significant emission reduction. Additionally, environmental impacts must be carefully considered (International Energy Agency, 2020).

Hydrogen is another potential solution for decarbonizing the energy sector. Green hydrogen, produced by electrolysis using renewable electricity, is a clean alternative to fossil fuels. The oil and gas sector can use its expertise in transportation and storage infrastructure to develop a hydrogen economy in Austria. The resulting hydrogen can provide a low-carbon alternative to traditional fossil fuels for areas which are difficult to decarbonize like heavy transportation or in industrial processes (Austrian Ministry for Climate Action, Environment, Energy, Mobility, Innovation and Technology, 2021). Green hydrogen production through electrolysis has several limitations, including high energy consumption and conversion losses due to low efficiency (Kondili et al., 2021). Although it is a clean alternative to fossil fuels, the overall efficiency of green hydrogen production is still relatively low, which limits its economic feasibility and scalability. The technology for producing green hydrogen is still in its early stages of development and has high capital costs associated with it (Budinis et al., 2020).

The study "One100 – Österreichs Nachhaltiges Energiesystem – 100% dekarbonisiert" outlines a roadmap for Austria to achieve 100% decarbonization of its energy system. It furthermore highlights the economic benefits coming along with renewable energy generation. It advocates for the expansion of renewable energy generation in Austria combined with efficiency measures and energy storage technologies to meet the country's energy needs (ONE100 - AGGM - Austrian Gas Grid Management AG,2021).

The oil and gas sector can play a role in the future energy system through technologies such as CCUS and hydrogen. This includes the re-purposing of existing gas infrastructure for hydrogen. The oil and gas sector furthermore has significant experience and knowledge in the energy industry which can support the energy transition to a decarbonized energy system. Within this scope are exploration and production, managing large-scale projects and developing new technologies. This can be valuable in the development and deployment of renewable energy technologies (United Nations Development Programme, 2019).

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ÜBER DEN WORLD ENERGY COUNCIL AUSTRIA

Die **Energiesysteme** sind **weltweit in Bewegung**. Mehr als eine Milliarde Menschen haben keinen Zugang zu leitungsgebundener Energie. In den aufstrebenden großen Volkswirtschaften kann die Armutsschwelle nur mit einem Mehr an Energie übersprungen werden. Andererseits bedingt die international gewünschte **Reduktion des CO_2-Ausstoßes** einen Systemwechsel. Die europäische Energieszene wird dominiert durch die Formen und die Auswirkungen der Energiewende.
Seit **mehr als 100 Jahren** steht der **World Energy Council**, mit dem Sitz in London, an der vordersten Front der Energiediskussion und versteht sich als **weltweite Denkfabrik** und Aktionsfeld, um Energie für alle sicher zu stellen. Der World Energy Council ist eine **UNO akkreditierte Organisation** und umfasst mehr als 3.000 öffentliche und private Organisationen in **annähernd 100 Staaten**.
Alle großen **internationalen Player** auf dem Sektor der Energiewirtschaft und –politik sind Teil des Weltenergierates. Wissenschaftliche **Studien und Prognosen** bieten den Akteuren in Politik, Wirtschaft und Wissenschaft die Informationen für zukunftsorientierte Entscheidungen. Im Vordergrund stehen die Interessen der Menschen und der Wirtschaft unseres Landes für eine **nachhaltige, effiziente und leistbare Energie**.
In Österreich sind maßgebende Unternehmen und Verbände Mitglied. Die nationale Organisation unterstützt **globale, nationale und regionale Energiestrategien** durch hochkarätige **Veranstaltungen** (alternative Mobilität, Energiewende, Energiespeicher), Studien und Rankings über die aktuelle Energiesituation im Konnex mit dem europäischen Umfeld. Querdialoge unter den Mitgliedsorganisationen und die Förderung von **Young Energy Professionals** sind ein wesentlicher Bestandteil.
Der **Nutzen für Mitglieder** liegt vor allem in folgenden Dienstleistungen des Weltenergierat Österreich:

1. Sicherung des Zuganges zu den Erkenntnissen des WEC, der einzigen **weltweiten Nicht-Regierungsorganisation**, die sich mit allen Fragen und Formen der Energie befasst.
2. Bereitstellung eines **Netzwerkes** mit nationalen und internationalen energiewirtschaftlichen Verbindungen.
3. Möglichkeit der aktiven Teilnahme an den energiewirtschaftlichen und statistischen **Arbeiten des WEC** und damit der aktiven Mitgestaltung von langfristigen strategischen Zielen.
4. Behandlung aktueller Fragen der Energiewirtschaft in den eigenen Gremien, in öffentlichen **Veranstaltungen** sowie durch Veröffentlichungen und damit Verbreitung von Fachwissen sowie Meinungsbildung in energiewirtschaftlichen und energiepolitischen Fragen.
5. Plattform für auf Konsens aufgebaute Lobbyingarbeit.

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Dipl. -Ing. Mag. Gerhard Gamperl (Geschäftsführer)
A-1040 Wien, Brahmsplatz 3

Tel.: +43-(0)1-5046986
Fax.: +43-(0)1-5047186
Mail: office@wec-austria.at

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