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Opinnäytetyön tavoitteena on luoda kattava kuva energiasektorin kasvihuonekaasupäästöregulaatiosta rahoituksen näkökulmasta. Opinnäytetyössä pyritään selvittämään, miten energiasektori on muuttunut, ja tulee muuttumaan tulevaisuudessa ilmastonmuutoksen hillitsemisen johdosta.

Opinnäytetyö on toteutettu kirjallisuuskatsauskenä. Työn lähteinä on käytetty erinäisten organisaatioiden tutkimuksia, asiakirjapapereita, sekä muita internetistä löytyviä lähteitä.

Opinnäytetyössä tehdystä selvityksestä käy ilmi, että yritys energiasektorin ohjaamiseksi vähäpäästöisemmäksi on globaalilla tasolla suuri. Monet kehityspakit, EU, OECD, sekä E3F pyrkivät omalta osaltaan hillitsemään ilmastonmuutosta rahoituskäytännöillään. Ilmaston lämpenemisen rajoittaminen 1,5-asteeseen vaatii kuitenkin vielä tiukempaa päästöregulaatiota valtioiden lainsäädännössä, sekä projektien rahoituskäytännöissä.

Avainsanat Kasvihuonekaasu, ilmastonmuutoksen hillitseminen, rahoitus, ja polttoaine

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ABSTRACT

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The objective of the thesis is to create a comprehensive overview of energy sector's greenhouse gas emission regulation from the point of view of finance. The aim is to examine how the energy sector has changed, and will change in the future due to the implications of climate change mitigation.

The thesis has been executed as a literature review. The sources of the thesis include varying organizations' studies, policy papers, and other sources that can be accessed through the internet.

The research carried out in the thesis makes it evident that the global-level efforts to decarbonize the energy sector are significant. Numerous MDBs, the EU, OECD, and E3F are trying to mitigate climate change through their financing policies. Yet, stricter policies regarding emissions need to be deployed within financing practices and countries' national laws in order to limit the global warming to 1,5 degrees.

Keywords Greenhouse gas, climate change mitigation, finance, and fuel

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LIST OF ABBREVIATIONS

ADB	Asian Development Bank
AfDB	African Development Bank
AIIB	Asian Infrastructure Investment Bank
ATR	Autothermal Reforming
BAT	Best Available Techniques
CCS	Carbon Capture and Storage
CCU	Carbon Capture and Utilization
CCUS	Carbon Capture, Utilization, and Storage
CFC	Chlorofluorocarbon
CI	Compression Ignition
CO ₂	Carbon Dioxide
COP21	21 st Conference of the Parties
COP26	26 th Conference of the Parties
DAC	Direct Air Capture
DF	Dual Fuel
DMC	Developing Member Country
E3F	Export Finance For Future
EBRD	European Bank for Reconstruction and Development
ECA	Export Credit Agency

ECG	Export Credit Guarantee
EED	Energy Efficiency Directive
EHS	Environment, Health, and Safety
EIB	European Investment Bank
ELP	Energy Lending Policy
ESF	Environmental and Social Framework
ESP	Environmental and Social Policy
ESPS	Environmental and Social Performance Standards
ESSP	Environmental and Social Safeguard Policies
ETS	Emissions Trading System
FAME	Fatty Acid Methyl Esters
G20	Group of 20
G7	Group of Seven
GDP	Gross Domestic Product
GFANZ	Glasgow Financial Alliance for Net Zero
GHG	Greenhouse Gas
HFC	Hydrofluorocarbon
HVO	Hydrotreated Vegetable Oil
IADB	Inter-American Development Bank
IBRD	International Bank for Reconstruction and Development

ICE	Internal Combustion Engine
ICSID	International Centre for Settlement of Investment Disputes
IDA	International Development Association
IDFC	International Development Finance Club
IEA	International Energy Agency
IED	Industrial Emissions Directive
IFC	International Finance Corporation
INDC	Intended Nationally Determined Contribution
IPCC	The Intergovernmental Panel on Climate Change
IRENA	International Renewable Energy Agency
IsDB	Islamic Development Bank
LAC	Latin America and the Caribbean
LDAR	Leak Detection and Repair
LNG	Liquefied Natural Gas
LOHC	Liquid Organic Hydrogen Carrier
MDB	Multilateral Development Banks
MIGA	Multilateral Investment Guarantee Agency
NDC	Nationally Determined Contribution
NO ₂	Nitrogen Dioxide
NO _x	Nitrogen Oxides

ODA	Official Development Assistance
OECD	Organization for Economic Co-operation and Development
PEM	Polymer Electrolyte Membrane
PFC	Perfluorocarbon
RED	Renewable Energy Directive
RFNBO	Renewable Fuels from Non-Biological Origin
RICE	Reciprocating Internal Combustion Engine
RMC	Regional Member Country
SDG	Sustainable Development Goal
SI	Spark Ignition
SIDS	Small Island Developing States
SMR	Steam Methane Reforming
SOEC	Solid Oxide Electrolyzer Cells
SOFC	Solid Oxide Fuel Cells
SPS	Safeguard Policy Statement
UNFCCC	United Nations Framework Convention on Climate Change
UNSD	United Nations Statistics Division
WHO	World Health Organization

1 INTRODUCTION

The objective of the thesis is to create a comprehensive overview of energy sector's greenhouse gas emission regulation from the point of view of finance, and the energy related financing practices and policies of selected institutions and organizations. The aim is to examine how the energy sector has changed, and will change in the future due to the implications of climate change mitigation. The purpose of the thesis is to also explain all of the greenhouse gases involved in the upstream, midstream, and downstream energy activities, as well as the most relevant global agreements regarding greenhouse gas emission regulation within the energy sector.

Climate change and greenhouse gases are discussed in the beginning of the thesis. Energy sector related greenhouse gases, and their sources, as well as the most important global agreements on greenhouse gases and climate change are introduced.

The greenhouse gases emitted from fuel combustion and production are discussed in the second chapter. The last chapter discusses the financing practices of varying multilateral institutions within the energy sector, and how climate change mitigation is reflected in them.

1.1 Effects of Climate Change

Climate change is caused by greenhouse gases accumulating to the Earth's atmosphere. The global warming has reached 1,1 degrees above pre-industrial levels to date.¹ Climate change has caused a multitude of phenomena that would not have occurred in the absence of anthropogenic greenhouse gas emissions. Many effects

¹ United Nations, 2021

are already experienced around the world. The consequences of climate change include more frequent and severe weather, higher death rates, dirtier air, higher wildlife extinction rates, acidification of oceans, and higher sea levels.²

Longer warm seasons extend the pollen season, exposing the population to increased allergic and asthmatic episodes. Higher concentrations of ground-level ozone are also associated with higher temperatures. Ground-level ozone is harmful to, for example, lungs, leading to increased hospital admissions and premature deaths.³

Sea level rise has accelerated by a double since the 90's. The melting of ice covers, glaciers, and thermal expansion of oceans caused by carbon dioxide absorption have accelerated the sea level rise. Ice loss in the Arctic is evident at the end of the summer. The area has decreased by 40 per cent since the late 70's. The ice loss is irreversible in some regions of the world.^{4,5}

Marine biodiversity loss is induced by acidification. Coral reefs and the thousands of species they inhabit are at risk, due to coral bleaching caused by rising water temperatures, hurricane surges, and waves scouring the reefs with sediment. The ocean's temperature rise, deoxygenation, and acidification are irreversible.^{6,7}

Climate change alters the habitats of many ecosystems. Some animal species have migrated to different regions due to the warming of their natural habitat. Some

² NRDC, 2016

³ Centers for Disease Control and Prevention

⁴ Intergovernmental Panel on Climate Change, 2021

⁵ National Oceanic and Atmospheric Administration, 2019

⁶ Intergovernmental Panel on Climate Change, 2021

⁷ National Oceanic and Atmospheric Administration, 2019

animal species, polar bears for one, are estimated to go extinct if the global warming increases significantly.⁸

Hot extremes, heatwaves, and extreme weather events are becoming more frequent with the global warming. Extreme weather events include floods, heavy rains, snow, wind, and temperature changes. Intensified hurricanes and cyclones are also expected to occur more frequently.^{9,10}

Weather extremes damage infrastructure, such as electricity and water, and disrupt livelihoods. Extreme heat can cause death in vulnerable people and outdoor workers. Food insecurity, poverty, and inequality are estimated to increase, while economic growth is estimated to become hampered as a result of climate change.¹¹

Low-income, rural population, and Small Island Developing States (SIDS) are amongst the most vulnerable to the impacts of climate change. SIDS are at risk of death, ill-health, and disrupted livelihoods due to flooding, sea level rise, and storms. Damage and adaptation costs can reach several percentages of GDP. Low-income population experiences direct effects of climate change in the form of disrupted livelihoods and food agriculture, and destructed homes. Indirect effects include food insecurity and the price of food. Health risks and death caused by malnutrition are expected to grow in low-income countries due to limited food availability. Rural areas are affected by limited supply of water for drinking and agricultural purposes. The negative impacts on rural livelihoods and agricultural productivity are most experienced in dry regions. Vulnerable communities and low-in-

⁸ Intergovernmental Panel on Climate Change, 2021

⁹ Intergovernmental Panel on Climate Change, 2014

¹⁰ National Oceanic and Atmospheric Administration, 2019

¹¹ Intergovernmental Panel on Climate Change, 2014

come populations experience the most effects due to limited ability to cope. Climate change will mainly affect human health by worsening already existing health problems.¹²

Climate change, environmental issues, and energy go hand in hand. Climate change mitigation entails major global shifts in energy production and consumption. Climate change mitigation policies can be harnessed to change the fuel consumption preferences away from high-carbon fuels and thus, also alter the prices of varying energy sources. Climate change and energy are not merely an environmental or quality of life issue, they also present threats to security and peace.¹³

1.2 Greenhouse Gas Emissions

The atmosphere consists mainly of nitrogen, oxygen, argon, and water vapor. Their combined share constitutes 95,5 per cent of the atmosphere. The remaining 0,5 per cent, 500 ppm unaccounted for, are trace gases. A plethora of compounds constitute the trace gases. Most notably, trace gases include what we know as greenhouse gases. The contribution of the 0,5 per cent to climate change is surprisingly large. Greenhouse gases include carbon dioxide, methane, nitrous oxide, and fluorinated gases, which are hydrofluorocarbons, perfluorocarbons, sulphur hexafluoride and nitrogen trifluoride. Most prominent greenhouse gases in the power sector are CO₂, CH₄, and N₂O. The focus of the thesis is mainly on these three greenhouse gases.¹⁴

The carbon dioxide concentration of the atmosphere was 413 ppm in the year of 2020. Carbon dioxide causes about 20 per cent of the Earth's greenhouse effect, being the second largest contributor after water vapor. Water vapor is a naturally

¹² Intergovernmental Panel on Climate Change, 2014

¹³ Shaffer, 2011

¹⁴ Dessler, and Parson, 2020

occurring greenhouse gas. Water vapor and naturally occurring carbon dioxide have kept Earth's temperatures suitable for human life. When discussing greenhouse gases and related emissions, naturally occurring water vapor and carbon dioxide are excluded. The greenhouse gases referred to in this thesis are of anthropogenic origin.¹⁵

The consequence of anthropogenic greenhouse gases is the increased warming of the atmosphere. However, the degree of global warming cannot be directly assumed by the amount of anthropogenic GHG emissions emitted. In general terms, about half of the carbon dioxide emitted remains in the atmosphere, and the other half is absorbed by land ecosystems and oceans. The carbon dioxide that remains in the atmosphere is referred to as airborne fraction. It is used to illustrate the balance between sinks and sources. Airborne fraction has stayed relatively stagnant until now because the sinks have grown at the same time as the emissions have increased. However, the future might look a bit different. Climate change causes droughts and wildfires, and they decrease the land ecosystems' ability to absorb carbon dioxide. A similar story can be told for oceans since ocean uptake is impaired due to higher sea-surface temperatures and decreased pH caused by carbon dioxide absorption.¹⁶

¹⁵ Dessler, and Parson, 2020

¹⁶ World Meteorological Organization, 2021

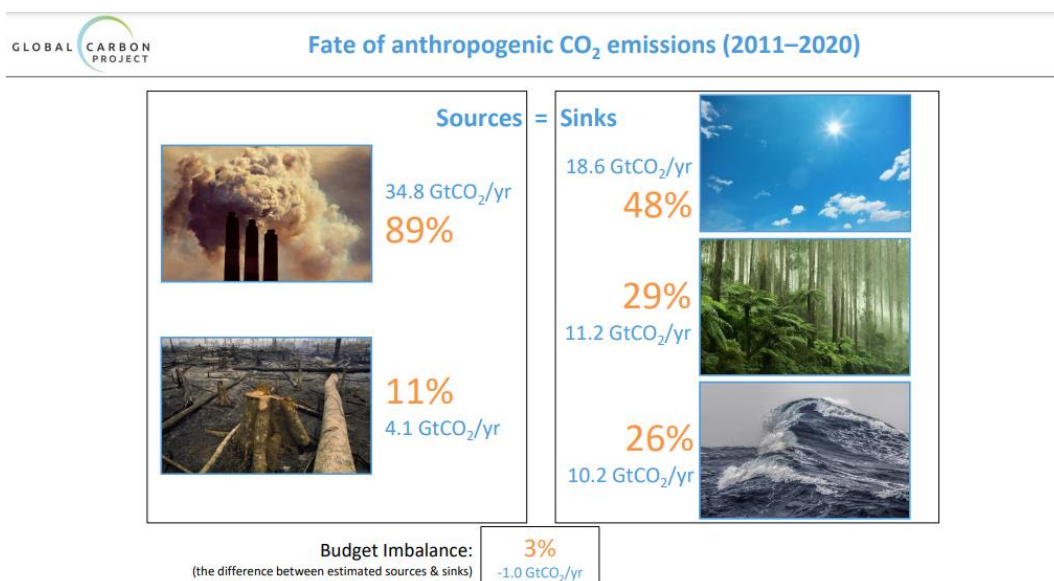


Figure 1. Fate of anthropogenic CO₂ emissions (2011–2020)¹⁷

This makes it evident that not all GHGs emitted get trapped in the atmosphere. However, even the GHGs that do remain in the atmosphere, do not equate the extent of global warming. Greenhouse gases cause the atmosphere to warm. As the atmosphere warms, it holds more water vapor, which is also a greenhouse gas. This phenomenon alone can even double the degree of global warming. Water vapor typically lasts in the atmosphere less than 10 days.¹⁸

1.2.1 Carbon Dioxide

Carbon dioxide is the largest contributor to anthropogenic greenhouse gas emissions and the warming of the atmosphere above pre-industrial levels. Carbon dioxide emissions originate mainly from fossil fuel combustion and industrial processes. Deforestation and changes in land use also increase the carbon dioxide concentration of the atmosphere. Fossil fuel utilization amounted to 31,5 giga

¹⁷ Global Carbon Project, 2021

¹⁸ Dessler, and Parson, 2020

tonnes of emitted carbon dioxide, and land use and deforestation contributed to an additional 5,7 giga tonnes in the year of 2020. Natural phenomena releasing carbon dioxide to the atmosphere include, for example, volcanic eruptions and respiration. Even though the COVID-19 pandemic had the effect of lowered fossil fuel consumption, the carbon dioxide concentration of the atmosphere is steadily rising.¹⁹ The pre-industrial level of carbon dioxide concentration in the atmosphere was 278 ppm. The concentration reached 413 ppm in the year of 2020. Thus, the concentration increased by 149 per cent compared to the pre-industrial level.²⁰

1.2.2 Methane

Methane is a potent greenhouse gas. Methane alone accounts for roughly 30 per cent of the global warming. Anthropogenic methane emissions come from sources, such as waste decomposition in landfills, rice agriculture and other agricultural activities, fossil fuel related activities, biomass burning, and livestock farming.

Methane emissions from fossil fuel production are largely attributed to fugitive emissions. Methane has a Global Warming Potential (GWP100) of 28, according to IPCC's Fifth Assessment Report.^{21,22} Anthropogenic methane emissions account for 60 per cent of the atmospheric concentration, and the remaining 40 per cent originates from natural sources. The atmospheric concentration of methane has increased from the pre-industrial level of 0,72 ppm to 1,88 ppm, as of 2020. The methane concentration of the atmosphere has increased by 262 per cent. Methane lasts in the atmosphere for about twelve years, while carbon dioxide lasts

¹⁹ UNFCCC, 2021

²⁰ World Meteorological Organization, 2021

²¹ Ritchie, and Roser, 2020

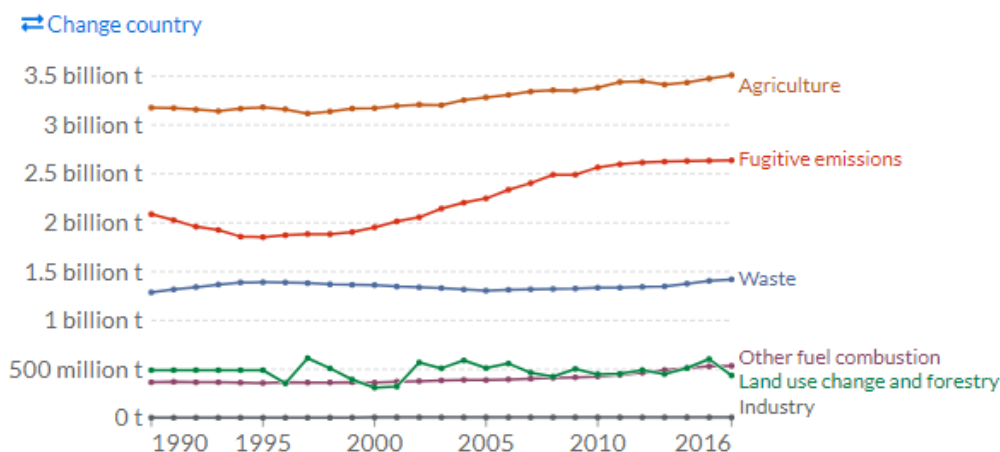
²² Greenhouse Gas Protocol, 2013

for several hundreds of years, and up to a thousand.²³ Recently methane emission mitigation has gained an increased attraction due to studied cost-efficiency of abatement and short-term climate benefits.²⁴

Methane emissions by sector, World

Methane (CH₄) emissions are measured in tonnes of carbon dioxide equivalents (CO₂e) based on a 100-year global warming potential value.

Our World
in Data



Source: CAIT Climate Data Explorer via. Climate Watch

Figure 2. Methane Emissions by Sector, World ²⁵

1.2.3 Nitrous Oxide

Nitrous oxide is another potent greenhouse gas, which originates from sources such as fertilizers, nitric acid production, and combustion of fossil fuels and biomass. Most of nitrous oxide emissions originate from fertilizer usage. Fertilizer is not only utilized by the agricultural crops, as intended, but soil's microbes use the nitrogen from the fertilizer to create nitrous oxide, which is then released to the atmosphere. The Global Warming Potential (GWP100) of nitrous oxide is 265

²³ Ritchie, and Roser, 2020

²⁴ World Meteorological Organization, 2021

²⁵ Ritchie, and Roser, 2020

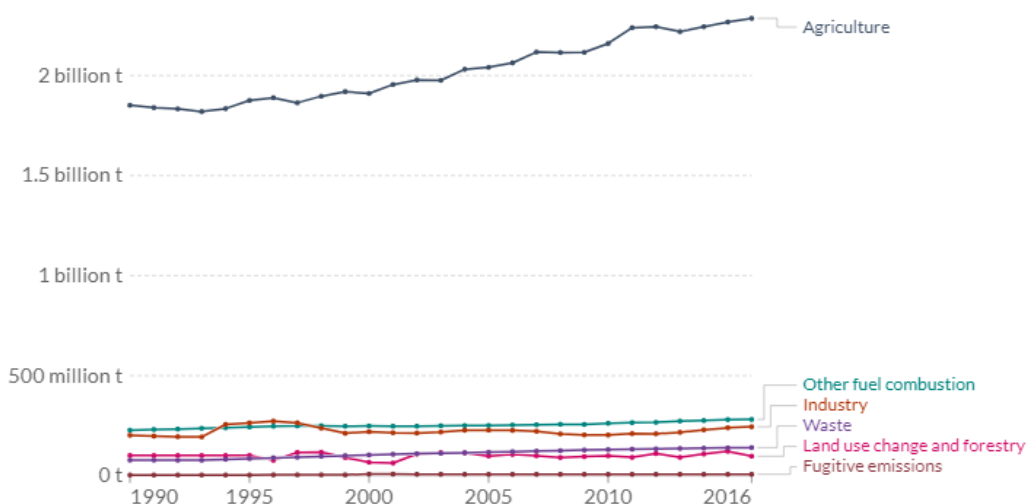
times higher than that of carbon dioxide.²⁶ Nitrous oxide is also destructive to the ozone layer and lasts in the atmosphere on average for 121 years.²⁷ Anthropogenic sources are responsible for 40 per cent of the atmospheric concentration of nitrous oxide. The concentration of nitrous oxide in the atmosphere is 0,33 ppm, being 123 per cent higher in the year of 2020 compared to pre-industrial levels, while manure and fertilizers constitute 70 per cent of anthropogenic nitrous oxide emissions.²⁸

Nitrous oxide emissions by sector, World

Nitrous oxide (N₂O) emissions are measured in tonnes of carbon dioxide equivalents (CO₂e) based on a 100-year global warming potential value.

Our World
in Data

Change country Relative change



Source: CAIT Climate Data Explorer via. Climate Watch

OurWorldInData.org/co2-and-other-greenhouse-gas-emissions/ • CC BY

Figure 3. Nitrous Oxide Emissions by Sector, World ²⁹

²⁶ Greenhouse Gas Protocol, 2013

²⁷ Ritchie, and Roser, 2020

²⁸ World Meteorological Organization, 2021

²⁹ Ritchie, and Roser, 2020

1.2.4 Other Greenhouse Gases

Fluorinated gases include hydrofluorocarbons (HFC), perfluorocarbons (PFC), sulphur hexafluoride, and nitrogen trifluoride. They are found in the atmosphere in small quantities, but they have high global warming potentials.³⁰

Chlorofluorocarbons were replaced by hydrofluorocarbons under the Montreal Protocol, because HFCs are less potent greenhouse gases than CFCs. They are used as aerosols and refrigerants.³¹

Perfluorocarbons are used as solvents and refrigerants. PFCs are also emitted from aluminium production. Nitrogen trifluoride is used in the semiconductor and chemical industry. It can be used to make rocket fuels and other chemicals.³²

Sulphur hexafluoride is another very strong GHG found in low amounts in the atmosphere. It is mainly emitted from the chemical industry and it can be used as an electrical insulator.³³

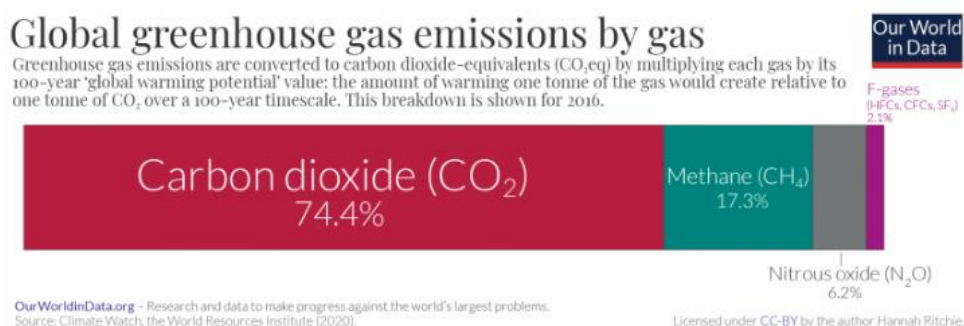


Figure 4. Global Greenhouse Gas Emissions by Gas (2016)³⁴

³⁰ Means, and Lallanilla, 2021

³¹ NASA, 2022

³² Ishii, and Kita, 2000

³³ World Meteorological Organization, 2021

³⁴ Ritchie, and Roser, 2020

1.3 Energy Production and Emissions

Energy production is the main contributor to anthropogenic greenhouse gas emissions (See Figure 5). Most of the emissions are caused by fossil fuel combustion. According to IPCC, 90 per cent of carbon dioxide emissions and 75 per cent of the total GHG emissions come from fossil fuel combustion in the high-income countries. Carbon dioxide constitutes 95 per cent of energy sector GHG emissions and the remaining five per cent is attributed to methane and nitrous oxide. The emissions from energy sector are divided into emissions from combustion, fugitive emissions, and emissions that do not involve combustion.³⁵

Oil, gas, and coal combustion are the largest contributors to carbon dioxide emissions. Cement and flaring represent a marginal contribution. Coal is the worst fossil fuel in terms of carbon dioxide emitted from its' usage. Natural gas emits the least carbon dioxide out of the fossil fuels.³⁶

The latest carbon dioxide emission increases from coal usage were detected in industrializing countries, such as China, South Africa, and India, while a decreasing trend was noted in industrialized countries. Russia and the US are included in the leading emitters of carbon dioxide from gas operations. Cement sector emissions can be largely attributed to China.³⁷

³⁵ Intergovernmental Panel on Climate Change, 2006

³⁶ Ritchie, and Roser, 2020

³⁷ Ritchie, and Roser, 2020

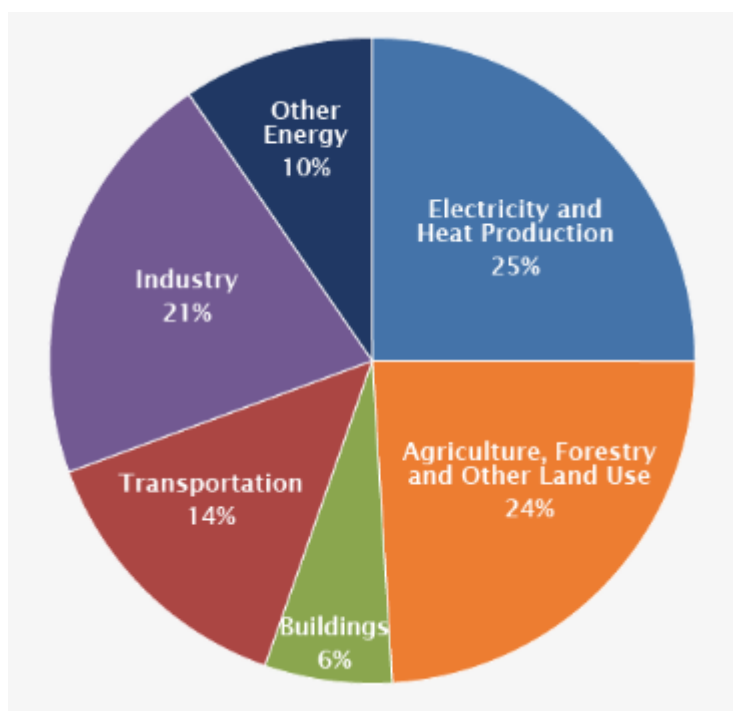


Figure 5. Global Greenhouse Gas Emissions by Economic Sector³⁸

The economic sector breakdown of total GHG emissions is illustrated in Figure 5. Electricity and heat production (25%) is dominant, followed by agriculture, forestry, and other land use (24%). Roughly a quarter of global emissions come from agriculture and land use, and the rest from energy.³⁹

³⁸ Environmental Protection Agency, 2010

³⁹ Environmental Protection Agency, 2010

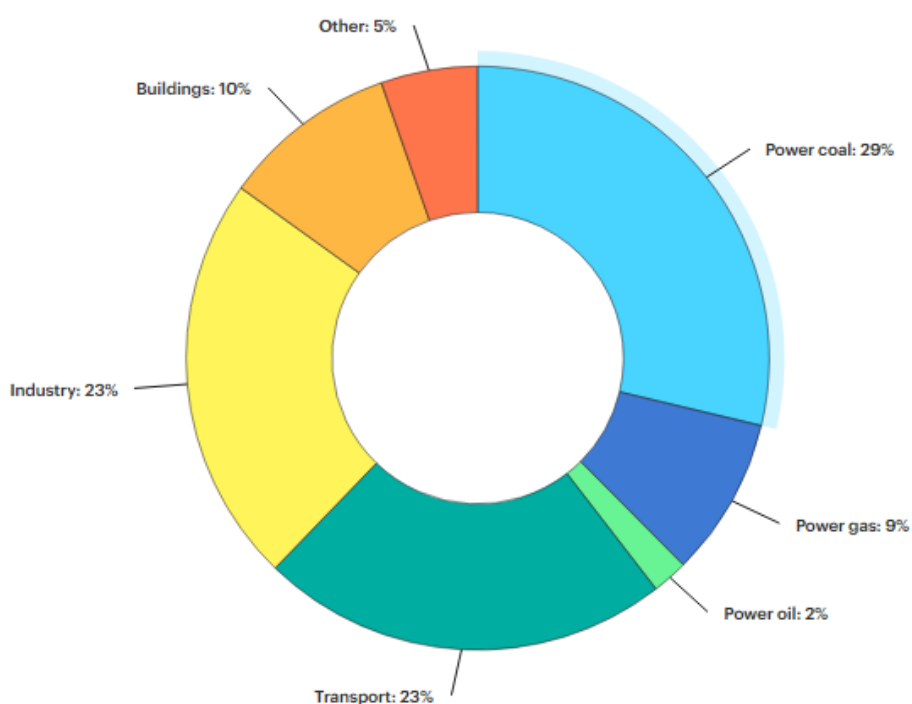


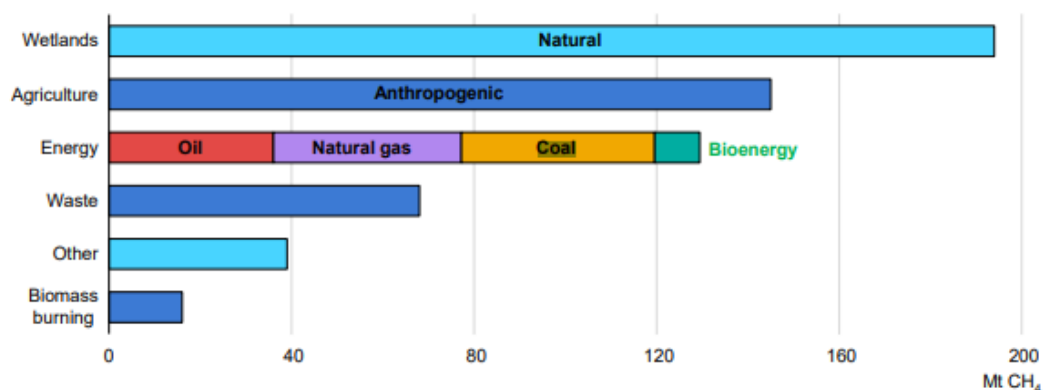
Figure 6. Global energy-related CO₂ emissions by sector⁴⁰

As illustrated in Figure 6, carbon dioxide emissions from the energy sector come mainly from transport (23%), power oil, gas, and coal (40%), industry (23%) and buildings (10%).

Energy production and agriculture are the leading methane emitting sectors. A third of the total methane emissions originate from fossil fuel sources (See Figure 7). Methane emissions in the energy sector come from coal, oil, gas, and bioenergy. Oil and gas combined generate most of the methane emissions in the energy sector. Both oil and gas were responsible for equal parts of emitted methane in the year of 2020.⁴¹

⁴⁰ International Energy Agency, 2021

⁴¹ International Energy Agency, 2021

Figure 1.1 Sources of methane emissions**Figure 7. Sources of Methane Emissions⁴²**

1.3.1 Upstream and Midstream Emissions

Emissions from fuel production, extraction, and processing are referred to as upstream emissions. Midstream emissions include emissions from distribution and transmission, while downstream emissions are mainly attributed to fuel combustion.⁴³ Methane up-, and midstream emissions are harder to abate from coal than oil and gas. Coal up-, and midstream methane abatement is expensive and more challenging because sources of methane emissions are dispersed and carry low concentrations.⁴⁴ Up-, and midstream oil and gas methane emission mitigation can be done at a very low cost, or no cost at all via fugitive emission abatement. Fugitive emissions and non-combustion emissions originate from venting, flash losses, leaks of equipment, and flaring, among others.^{45,46,47}

⁴² International Energy Agency, 2021

⁴³ Nature Communications, 2020

⁴⁴ International Energy Agency, 2021

⁴⁵ Intergovernmental Panel on Climate Change, 2019

⁴⁶ Intergovernmental Panel on Climate Change, 2019

⁴⁷ Laconde, 2018

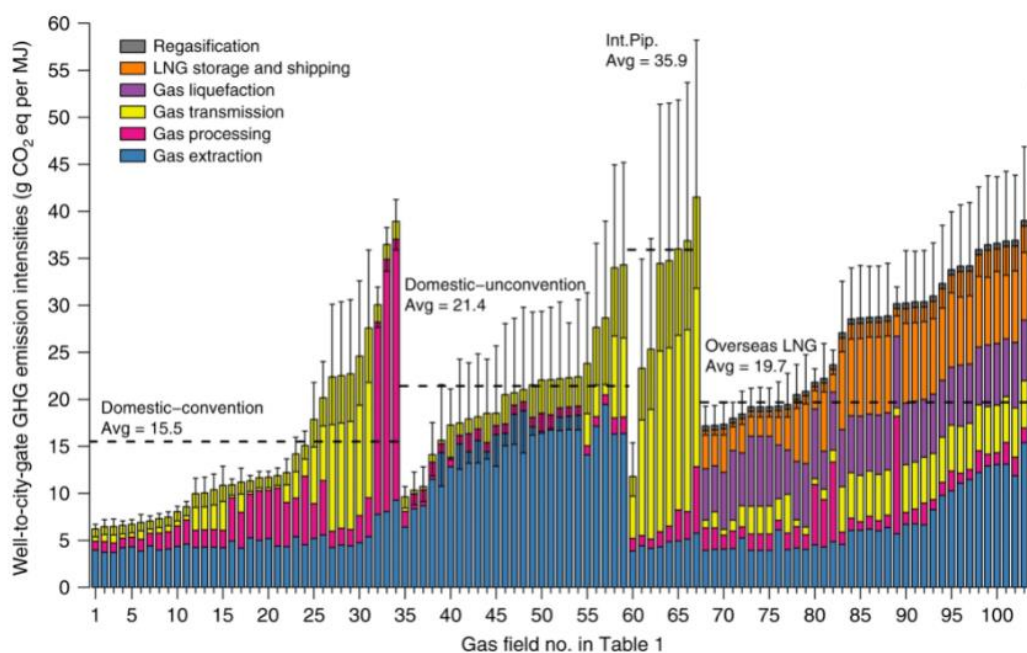


Figure 8. Well-to-city-gate GHG intensities of natural gas supplies from individual fields to China using the 100-year timeframe global warming potential (GWP100)⁴⁸

It is estimated that fugitive emissions can be reduced by 66 per cent if a leak detection and repair (LDAR) program is carried out on a quarterly basis. The LDAR program detects unintentional leaks from up-, and midstream activities. These unintentional leaks are often caused by faulty equipment and components. Upstream emissions are leak detected in processing, gathering and wells, and midstream emissions in distribution and transmission systems. Emissions could be further decreased if the procedure was done more frequently. However, it is usually not feasible.⁴⁹

⁴⁸ Nature Communications, 2020

⁴⁹ International Energy Agency, 2021

Other feasible ways to abate fugitive leaks and non-combustion emissions in up-, and midstream activities are mitigating vapor leaks with recovery units, avoiding venting with upgraded equipment, and so on.^{50,51}

1.3.2 Energy Efficiency

Efficiency describes how well energy is converted into useful work. It is defined as the relation of output energy to input energy. Energy losses occur throughout the stages of thermal power generation. In order to save fossil fuel sources, the efficiencies of thermal power plants need to be improved. The main prime mover types used in conventional thermal power plants are gas turbine (GT), boiler, and reciprocating internal combustion engine (RICE).⁵²

The reciprocating internal combustion engine has a higher electrical efficiency than the single cycle gas turbine. In a CHP (combined heat and power) application waste heat from the exhaust gas and cooling circuits of RICE are recovered. RICE can achieve a 90 per cent fuel efficiency, where around 44 per cent generates electricity, and the rest heat and cool.^{53,54,55}

Some general efficiencies that can be achieved for different power plant prime mover types are presented in Table 1.

⁵⁰ International Energy Agency, 2021

⁵¹ International Energy Agency, 2022

⁵² Zhang, 2020

⁵³ Krarti, 2018

⁵⁴ Environmental Protection Agency, 2015

⁵⁵ Wärtsilä, 2020

Table 1. BAT-associated Energy Efficiency Levels (BAT-AEELs) for Selected Types of Combustion Units⁵⁶

Type of combustion unit	Net electrical efficiency, new unit (%)	Net total fuel utilization (%)
New Coal-fired boiler plant > 1000 MW _{th}	45-46	75-97
New Oil-fired boiler plant	>36,4	80-96
New Oil-fired RICE single cycle	41,5-44,5	-
New Oil-fired RICE combined cycle	>48	-
New Oil-fired open cycle gas turbine	>33	-
New Oil-fired combined cycle gas turbine	>40	-
New Gas-fired boiler	39-42,5	78-95
New Gas engine	39,5-44	56-85
>50 MW _{th} New open cycle gas turbine	36 – 41,5	-
Gas-fired combined cycle gas turbine		65-95
New 50 - 600 MW _{th}	53-58,5	
New > 600 MW _{th}	57 – 60,5	

⁵⁶ European Union, 2017

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Net electrical efficiencies are for electricity generation only power plants. The net total fuel utilization represents how much of the energy contained in the fuel can be utilized when the CHP plant in question produces both heat and electricity. Achievable net total fuel utilization percentage depends mainly on the properties of the produced heat, such as outlet steam pressure and temperature.⁵⁷

1.4 Global Agreements

1.4.1 Kyoto Protocol

UN Framework Convention on Climate Change (UNFCCC) was the first major convention on addressing climate change. Nowadays almost all of the world's countries are members of the convention. UNFCCC is the parent treaty of the Kyoto Protocol.⁵⁸

The Kyoto Protocol was introduced in the Conference of the Parties held in Kyoto 1997. The Kyoto Protocol was the world's first legally binding treaty on greenhouse gas emissions, implemented in 2005.⁵⁹ The protocol established a concrete goal of reducing GHG emissions within industrialized countries by five per cent compared to 90's level to address climate change. The industrialized countries that had obligations under the treaty are called Annex I parties. The cumulative per-

⁵⁷ European Union, 2017

⁵⁸ Shaffer, 2011

⁵⁹ European Union

centage was not applied across the board. Each Annex I party had their own 'assigned target' for emission reduction, differing from the collective percentage of five. The EU, for example, had a target of reducing emissions by 8 per cent.⁶⁰

The Annex I parties determined the means of reaching their goals on a national level. The Kyoto Protocol accounted for six GHG emissions in six sectors. The sectors were agriculture, energy, waste, land use, industrial processes and solvents and other product use. A seventh greenhouse gas was added to the second commitment period. The countries could decide for themselves which GHGs and sectors to target, giving leeway to determine and execute the most cost-efficient pathway to reduce emissions.⁶¹

The protocol established market-based mechanisms of emission permit trade for the Annex I parties to use if the countries could not reach their assigned amount of reduction domestically. The trade was done via 'Kyoto Units' using three market mechanisms. The mechanisms included joint implementation, clean development mechanism and emission trading. Emission trading enabled countries which exceeded their emission reduction targets to sell 'emitting rights' to those who did not achieve the required reduction. The mechanism allowed the cumulative reduction to remain unchanged, but rather be redistributed among Annex I parties. Joint implementation and clean development mechanism facilitated projects to other countries. The mechanisms were utilized when emission reductions could not be done cost-effectively, or otherwise, within the country's own borders.^{62,63}

The first commitment period of the protocol started from 2008 and ended in 2012. The 37 industrialized countries that were asked to join the collective effort in the

⁶⁰ UNFCCC

⁶¹ UNFCCC, 2008

⁶² UNFCCC

⁶³ UNFCCC

first commitment period included a good chunk of current EU members, Australia, Canada, Japan, Russia, the US, among others. However, all of these countries did not ratify the protocol. The countries that ratified the agreement constituted only 18 per cent of global emissions. The USA was one of the developed countries that did not ratify the treaty.⁶⁴

The Kyoto Protocol held merely developed countries accountable for emission reduction, and the reasoning behind the decision was that developed countries have initiated the climate change as the current and historic emitters of GHG emissions. China and some developing countries stated that the industrialized countries' history of emitting GHGs has led to the current global threat that climate change opposes. The opinion was that industrialized countries shall bear the burden of decreasing emissions, alluding to that their economies developed to their current standings through their access to cheap energy.⁶⁵

The problem with the protocol was that countries like China and India were not asked to join the efforts, even though their energy consumption and GHGs were on the rise. It did not take until 2007 for China to surpass the USA as the biggest emitter of GHGs. In short, the major issue of the protocol was that no developing countries were put under obligation, and the largest emitters, like the US and China, did not get involved.⁶⁶

The Kyoto Protocol also had some unfortunate issues with the reporting of GHG emissions. Some countries moved their domestic production processes to countries with no obligation under the treaty. Reporting was seen as inaccurate, with no real follow-ups made on the projects' actual ability to reduce GHG emissions.

⁶⁴ European Union

⁶⁵ Shaffer, 2011

⁶⁶ Shaffer, 2011

Another issue of the agreement was that there were little to no penalties in place for violations of the treaty.⁶⁷

The second commitment period of the treaty lasted between 2013 and 2020. The participants of the second commitment period set a goal of reducing emissions cumulatively by eighteen per cent compared to the 90's level. Countries that committed to reduce their GHG emissions under the Kyoto Protocol's second commitment period included EU, Iceland, Australia, and a few other countries. The second commitment period failed to engage most of the emitters of GHG emissions. Nitrogen trifluoride was added as a seventh greenhouse gas to be accounted for during the period, otherwise the same Protocol was implemented.^{68,69}

1.4.2 Paris Agreement

The Paris Agreement is a legally binding agreement on climate change, established in 2015 at 21st Conference of the Parties. UNFCCC is the parent treaty of the Paris Agreement and the Kyoto Protocol. The Agreement was monumental, because for the first time ever, almost all of the world's countries committed to reduce GHG emissions. The treaty has been ratified by 193 countries today. These countries committed to a joint effort of limiting the warming of the Earth's atmosphere to 2 degrees, and to go even further and strive for 1,5 degrees.⁷⁰

The countries created NDCs, Nationally Determined Contributions, under the Agreement, which outline national policies and plans of reducing emissions. NDCs are outlined and defined on a national level by each country's government. NDCs

⁶⁷ Shaffer, 2011

⁶⁸ European Union

⁶⁹ European Union, 2015

⁷⁰ UNFCCC

are a country's plan to reduce emissions and adapt to climate change. The countries set Intended Nationally Determined Contributions, INDCs, in preparation of COP21. INDCs were published to demonstrate the level of ambition countries had before the COP. The updated NDCs were bound to be published by 2020. NDCs have regular reporting requirements on implementation, emissions, and their achieved reduction. They are updated every five years to match the current level of a country's ambition. Collective progress towards the Paris Agreement goals is assessed every five years and the scope of climate action is reassessed. The next assessment will be done in 2023.^{71,72}

The Nationally Determined Contributions Synthesis Report was made in preparation of COP26. The Synthesis Report puts together information on all the so far received NDCs. It shows that many countries provided concrete and numerical mitigation targets, while others provided plans and strategies without quantifiable targets. All mitigation sectors were covered in the NDCs by most countries. The most common GHGs covered by the NDCs are carbon dioxide, methane, and nitrous oxide. Many also include HFC emissions, and some PFC, sulfur hexafluoride, and nitrogen trifluoride emissions. Most of the updated NDCs show more ambitious plans made for 2025 and 2030 compared to INDCs. Most countries started implementing their NDCs on 1.1.2021.⁷³

Almost every country named domestic mitigation measures as their main tool for reducing emissions. The most common domestic measure is increasing the share of renewable energy, especially in electricity generation. Increasing the share of electricity in energy supply was frequently mentioned as well. Other common domestic measures are increasing energy efficiency of buildings, low-carbon fuels,

⁷¹ COP26, 2021

⁷² UNFCCC

⁷³ UNFCCC, 2021

waste-to-energy, and manure management. Frequent themes included carbon pricing, circular economy, and energy efficiency. The most popular carbon sequestration measures were reforestation, afforestation, and reducing deforestation.⁷⁴

If the NDCs announced were fully implemented, global emissions would peak before 2030. However, the carbon budget of limiting warming to 1,5 degrees would be used up by 89 per cent in 2030 if all NDCs were implemented. The carbon budget to limit warming to 2 degrees would be used up by 39 per cent in 2030. The estimation raises concern and entails that immediate action needs to be taken to limit emissions before the year of 2030, especially if the warming would like to be kept under 1,5 degrees. The NDCs announced before COP26 need to be updated to more ambitious ones to get there.⁷⁵

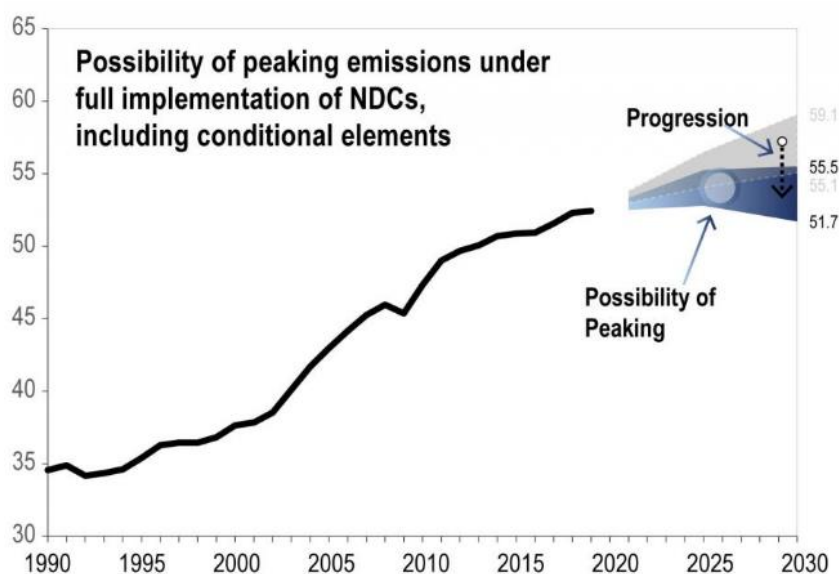


Figure 9. Possibility of Peaking Emissions Under Full Implementation of NDC's ⁷⁶

⁷⁴ UNFCCC, 2021

⁷⁵ UNFCCC, 2021

⁷⁶ UNFCCC, 2021

The Paris Agreement includes a notion that developed countries should help developing countries reach their NDCs through climate finance. Climate finance is directed towards mitigation and adaptation. Developing countries are assisted not only through finance, but also other forms of capacity building. The other forms include, for example, technology development, training, and public awareness. Capacity building is generally done regionally, multilaterally, and bilaterally.⁷⁷

The Paris Agreement developed a technology framework, which has a purpose of accelerating innovation and technological advancement to create a more sustainable future. The role of innovation is defined as an efficient and long-term response to climate change. It is used as means of promoting sustainable development and economic growth. The Paris Agreement emphasizes that all financial flows need to be aligned with the Agreement's goals in order to mitigate climate change and achieve required GHG emission reductions.⁷⁸

Paris Agreement states that in order the global warming to be limited to the desired level, countries need to reach their peak GHG emissions as soon as possible. It was recognized that developing countries will take longer to do so. The responsibility of the developed countries is to both, reducing domestic emissions, and helping developing countries reduce theirs.⁷⁹

The Paris Agreement acknowledges that mitigation and adaptation are interconnected. While adaptation is important, mitigation is equally important because it reduces the future need for adaptation. On the other hand, adaptation must be

⁷⁷ UNFCCC

⁷⁸ UNFCCC

⁷⁹ UNFCCC

funded because countries are already experiencing the consequences of climate change.⁸⁰

1.4.3 Glasgow 26th United Nations Climate Change Conference of the Parties

The Conference of the Parties, COP, is a conference for the members of the United Nations Framework Convention on Climate Change (UNFCCC). Almost all of the world's countries are members of the Convention. The 26th COP was held in Glasgow in 2021. The COP was originally planned to be held in 2020, but due to the COVID-19 pandemic, the COP was postponed by a year. COPs are one of the largest international meetings in the world. Each country is represented in COPs by officials, which participate in negotiations between governments. Despite the COVID-19 pandemic, COP26 was the biggest COP to date. Fifty thousand delegates and 120 world leaders were able to attend the conference.⁸¹

As a result of COP26, the Glasgow Climate Pact was signed by each participant. The purpose of the Glasgow Climate Pact is to accelerate the efforts to mitigate climate change. The Pact keeps the hope alive on limiting global warming to 1,5 degrees, but still recognizes that this will only be achieved if each participant sticks to their pledges and takes concrete steps to implement them. The themes for COP26 were mitigation, adaptation, finance, and collaboration. The Paris Rulebook was also finalized.⁸²

⁸⁰ UNFCCC, 2015

⁸¹ COP26, 2021

⁸² COP26, 2021

The COP accomplished something monumental, 153 countries pledged to net zero targets, covering 90 per cent of the world's GDP and 90 per cent of global emissions. The Nationally Determined Contributions, NDCs, were renewed by 153 countries. Many cities, regions, and states also committed to net zero targets.⁸³

The Paris Rulebook holds the rules for implementing the Paris Agreement. The Rulebook was completed and now includes unified practices in emission reporting, new standards for global carbon markets, and universal timelines for NDCs to be implemented and met.⁸⁴

The Breakthrough Agenda was pledged by 40 countries. The Breakthrough Agenda has a goal of making sustainable and clean alternatives the cheapest, most attractive, and most accessible options across emission-intensive sectors. The sectors included in the agenda are energy, transport, steel production, and hydrogen. The 'hydrogen breakthrough' goal states that inexpensive low carbon and renewable hydrogen needs to be made globally available. Clean sources of electricity have already become the cheapest in most countries, especially wind and solar. New gas and coal power plants are more expensive than solar and wind installations in over two thirds of the world.⁸⁵

⁸³ COP26, 2021

⁸⁴ COP26, 2021

⁸⁵ COP26, 2021

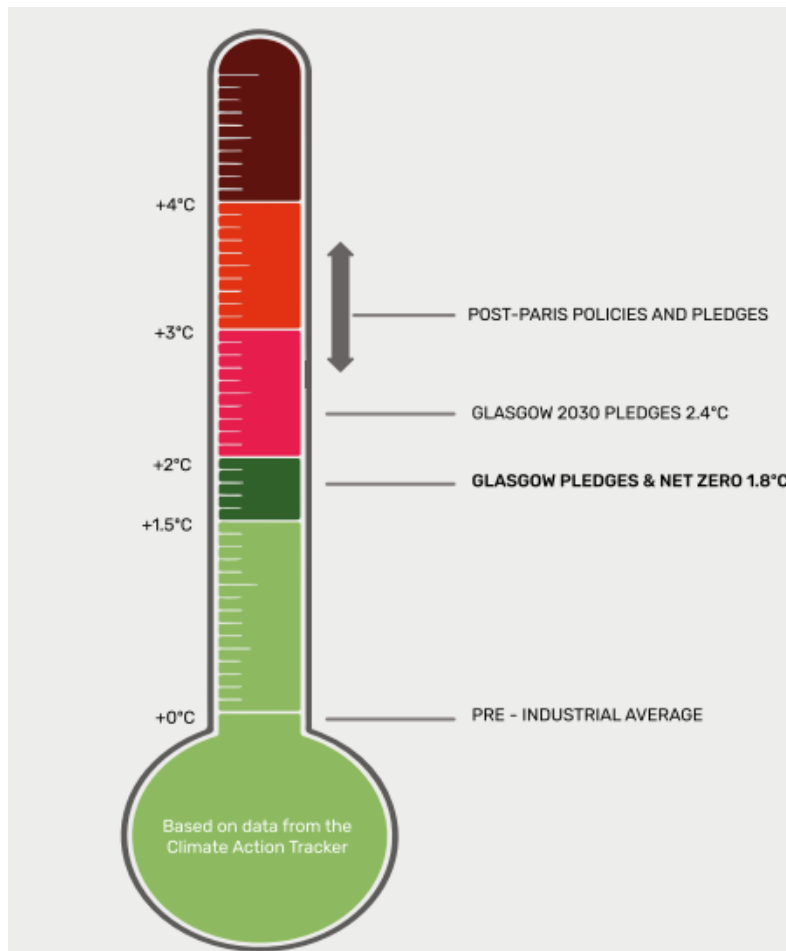


Figure 10. Glasgow Pledges & Net Zero ⁸⁶

Figure 10 illustrates the global warming levels if certain pledges were commissioned in practice and in a timely manner. The INDCs committed to in Paris did not reach the 1,5-degree warming limit. In fact, the INDCs would result in a warming of 3 degrees by 2100. To reach the 1,5-degree warming target, emissions must be cut in half in the next ten years, and net zero emissions reached by 2050.⁸⁷

⁸⁶ COP26, 2021

⁸⁷ COP26, 2021

If all pledges made in COP26 are implemented, the global warming could be limited to 1,8 degrees, achieving the 2-degree warming limit. Future pledges and policies have the potential to nudge the number below the 1,5-degree limit. In other words, new policies and pledges still must be made and implemented to reach the optimistic 1,5-degree warming limit.⁸⁸

Despite being the main cause of climate change, oil, gas, and coal subsidies were explicitly brought into discussions for the first time in the COP history in Glasgow. Intentions of ending direct public financial support for international unabated fossil fuel energy projects were announced by 34 countries and 5 public financial institutions. The 34 countries include numerous developing countries, Export Finance for Future coalition's member countries, and all G7 countries, except Japan.^{89,90}

Coal is the largest individual contributor to climate change. Unabated coal is the most emission intensive fossil fuel. Phasing out coal has been pledged by 65 countries. Twenty of the countries are new, making the commitment during the COP26. The list of countries includes all major coal financier countries who have pledged to stop international financial support for coal projects. The pledge has already been implemented in these countries. However, the original plan to 'phase out' coal was changed in the last minute to 'phasing down' coal by the request of India. India argued that phasing out coal is unjust for developing countries and can hinder their development. The request from India came as no surprise since it has had plans of increasing its' coal capacity in power generation. Most of the parties were displeased with the changes made, saying that the ambition level is lacking in reaching the goal of the Paris Agreement. However, any agreement was deemed

⁸⁸ COP26, 2021

⁸⁹ COP26, 2021

⁹⁰ Export Finance for Future, 2021

better than no agreement at all.⁹¹ Thus, in addition to 65 countries ‘phasing out’ coal, 190 countries signed the agreement to ‘phase down’ coal. The 190 countries amount to almost all of the world’s countries. As a result, coal power is expected to reduce by 76 per cent. An additional commitment was made to help developing countries transition from coal to clean energy with 20 billion worth of financing.⁹²

Transport by road accounted for 10 per cent of global GHG emissions. Half of oil consumption is facilitated by road transport. The issue was discussed in COP26, and action was taken by initiating the mass market for zero emission vehicles. Thirty countries, 6 manufacturers, 28 fleet owners, 43 cities and regions, and 15 finance investors and institutions pledged that new polluting vehicles are not sold after 2040. Some countries, including the EU will enforce the policy even earlier, in 2035.⁹³

Methane emissions were brought into discussions as well. Global Methane Pledge was signed by 103 countries. The aim of the pledge is to reduce methane emissions by a third by 2030 compared to 2020 levels. Methane has caused about 30 per cent of current global warming. Pledgers cover 70 per cent of the world’s GDP. Methane emission reduction policymaking will target oil and gas, agriculture, and waste sectors.⁹⁴

Multilateral Development Banks (MDBs) are now almost all agreeing to align their operations with the Paris Agreement. The planned schedule for enforcement is 2025. Some MDBs have already aligned their activities with the agreement. All

⁹¹ United Nations

⁹² COP26, 2021

⁹³ COP26, 2021

⁹⁴ United Nations, 2021

eight major MDBs have jointly committed to increase climate finance. The 26 major bilateral development finance institutions, IDFC, committed to mobilize 1,3 trillion in climate finance and end the financial support of unabated coal.⁹⁵

An emphasized talking point of the COP was the importance of finance in combating climate change. Developed countries try to mobilize 100 billion of climate finance for the benefit of developing countries annually. Targets for increasing adaptation finance were made for the first time in the COP history. Net zero by 2050 target requires mobilizing trillions of private finance. It is emphasized that climate must be reflected in each financial decision in private investment, governmental actions, and the actions of international financial institutions. Public finance is essential for climate change mitigation because transitioning the energy sector is going to require major investments in new infrastructure. Private finance is needed for innovation and technological advancement.⁹⁶

1.4.4 United Nations 2030 Agenda for Sustainable Development

The 2030 Agenda for Sustainable Development was launched by a UN Summit in New York, September 2015. The purpose of the agenda is to eradicate poverty in all of its' forms. The UN 2030 Agenda envisages a world of universal respect for human rights and human dignity, the rule of law, justice, equality, and non-discrimination. It was enforced in 2016.⁹⁷

The United Nations 2030 Agenda for Sustainable Development consists of seventeen Sustainable Development Goals (SDGs), which were implemented in 2015 among all member countries of the United Nations.

⁹⁵ COP26, 2021

⁹⁶ COP26, 2021

⁹⁷ Srivarnam Organization



Figure 11. Sustainable Development Goals⁹⁸

For the sake of this thesis, the focus will be on Sustainable Development Goal 7, which covers affordable and green energy. However, it is worthwhile to acknowledge that the GHG emission increase impairs the achievement of many Sustainable Development Goals.⁹⁹ SDG7 consists of the following targets: universal access to sustainable, reliable, affordable, and modern energy services, increased share of renewables in the energy mix, increased energy efficiency, increased infrastructure investments, and accelerated research and development of clean technologies through international collaboration. Lastly, all above mentioned targets need to be achieved in developing countries as well.¹⁰⁰

IEA, IRENA, UNSD, World Bank, and WHO prepared a progress report in 2021 to analyze if progress has been made towards the goals set in SDG7. The conclusion is that the goal is not on track, especially in the most vulnerable countries. It is estimated that 30 million people might have lost their access to electricity during

⁹⁸ SDG Tracker, 2018

⁹⁹ Kwakwa, 2020

¹⁰⁰ IEA, IRENA, UNSD, World Bank, WHO, 2021

COVID-19. Electricity would have to be provided to 760 million people to reach the 2030 goal of access for all. Clean cooking access would need to be provided to 2,6 billion people by 2030. The findings of the progress report can be found in an Appendix at the end of the document.¹⁰¹

¹⁰¹ IEA, IRENA, UNSD, World Bank, WHO, 2021

2 FUEL RELATED GREENHOUSE GAS EMISSIONS

2.1 Combustion Emissions

2.1.1 Downstream Emissions

Downstream emissions in the energy sector are largely attributed to fossil fuel combustion. This chapter discusses fossil fuel combustion specific GHG emissions.

Fossil fuels are hydrocarbons, meaning that they mainly consist of hydrogen and carbon, with some additional impurities. Directly emitted carbon dioxide emissions from combustion can be equated to the carbon content of the fuel and its consumption. Efficient fuel combustion ensures oxidation of the maximum amount of carbon present in the fuel. When the carbon content of the fuel is fully oxidized, a standard amount of CO₂ emissions is emitted from the combustion. Otherwise the fraction oxidized is needed to determine carbon dioxide emissions. Gaseous and liquid fuels show low variability in oxidation. Fraction oxidized varies more for coal and other solid fuels. As a reference, less than 1 per cent of carbon is not oxidized in natural gas combustion. Because the effect of combustion conditions on carbon dioxide emissions is negligible, the carbon dioxide is directly related to the carbon content and consumption of the fuel. Natural gas has the highest hydrogen to carbon ratio out of the fossil fuels, meaning that its combustion emits the least amount of carbon dioxide compared to other fossil fuels. Coal has the lowest hydrogen to carbon ratio, emitting the most carbon dioxide during its combustion compared to other fossil fuels.¹⁰²¹⁰³

¹⁰² Greenhouse Gas Protocol, 2005

¹⁰³ Toossi, 2011

Direct measuring of carbon dioxide emissions can be expensive, so often the preferred method of determining CO₂ emissions is to calculate based on fuel consumption and using emission factors.¹⁰⁴

Table 2 shows some default emission factors for stationary combustion in energy industries, provided by IPCC. The carbon content varies within the listed fuels, but the defaults give an estimation. Natural gas compositions can vary. The gas is mainly composed of methane, but can include small quantities of ethane, propane, butane, and heavier hydrocarbons.¹⁰⁵

Table 2. Default CO₂ Emission Factors for Stationary Combustion in the Energy Industries (kg of carbon dioxide per TJ on a Net Calorific Basis)¹⁰⁶

Fuel	Default emission factor of CO ₂ (kg CO ₂ /TJ)
Natural gas liquids	64 200
Gas/Diesel Oil	74 100
Natural Gas	56 100
Biodiesels	70 800
Other Liquid Biofuels	79 600
Other Biogas	54 600

¹⁰⁴ Greenhouse Gas Protocol, 2005

¹⁰⁵ Intergovernmental Panel on Climate Change, 2006

¹⁰⁶ Intergovernmental Panel on Climate Change, 2006, chapter 1

Direct carbon dioxide emissions from stationary combustion are straightforward to calculate. The same does not apply to methane and nitrous oxide since these emissions are more variable, and are affected by many factors, such as fuel type, composition, age of equipment, load, combustion technology, oxidation factor, combustion conditions, and emission control technology.¹⁰⁷

Direct nitrous oxide emissions are heavily dependent on the air-fuel mix, combustion temperature, and residence time.¹⁰⁸ The combustion of natural gas and biogas emit only trace values of nitrous oxide in steady state operating conditions. The peak of nitrous oxide emissions is emitted during lean blow-out, ignition, and unstable blowoff. One study done on boiler combustion shows that once steady state operation is achieved after ignition, nitrous oxide is no longer emitted, while NO₂ and NO become the dominating species. Nitrous oxide and NO did not coincide during any of these events. It was evident that at steady state, nitrous oxide was a very reactive intermediate that was quickly destroyed before being emitted from a flame. Nitrous oxide emissions were stimulated when hydrogen was blended with natural gas.¹⁰⁹

Methane emissions are mostly affected by combustion efficiency, prime mover type, and the methane content of the fuel. Methane slip from reciprocating lean burn gas engine operation is further discussed in the following chapter.

¹⁰⁷ Intergovernmental Panel on Climate Change, 2006, chapter 2

¹⁰⁸ Lee, Yun, Lee, Kim, Yun, and Hong, 2021

¹⁰⁹ Colorado, McDonell, and Samuelsen, 2016

Direct measurements are often preferred for methane and nitrous oxide emissions due to their variable nature. Continuous monitoring, however, is expensive. Periodical measurements are usually preferred.¹¹⁰

2.1.2 Methane Slip

Methane slip occurs when methane evades combustion in an engine. The unburned methane escapes with flue gases, and partially through the crankcase ventilation. In addition to being emitted to the atmosphere as a greenhouse gas and a precursor for ozone, methane slip is also wasted fuel. Lean burn gas engine types cause higher methane slip emissions than high pressure gas engine types. Spark-ignition (SI) and dual-fuel (DF) engines are lean burn gas engine types, and the compression-ignition (CI) engine is a high-pressure gas engine type. Methane slip from lean burn gas engine types is mainly caused by crevices, also called dead volumes, cylinder scavenging, and cold walls of the combustion chamber.^{111,112,113}

The complete combustion of methane requires high temperatures and a sufficiently long residence time. Methane can evade combustion by getting trapped into crevices. Minimizing crevices in the combustion chamber decreases the methane slip. An example of crevice volume is the area between the top piston ring and the upper edge of piston crown. By bringing the top piston ring up, the crevice volume is decreased.^{114,115,116}

Inlet and exhaust valves are sometimes open simultaneously during combustion. This event is called scavenging, during which unburned methane escapes through

¹¹⁰ Intergovernmental Panel on Climate Change, 2006

¹¹¹ MAN

¹¹² EUROMOT, 2012

¹¹³ Wärtsilä, 2020

¹¹⁴ MAN

¹¹⁵ EUROMOT, 2012

¹¹⁶ Wärtsilä, 2020

the exhaust valve. Combustion and control system optimization have the potential of reducing the time the valves are simultaneously open, and thus also reducing the methane slip. The hydrocarbon emissions of lean burn gas engines have decreased substantially since the 90's due to reductions in cylinder scavenging and crevice volumes of the cylinder, as well as improvements in combustion control systems, such as ignition stability.^{117,118,119}

Methane slip can be reduced by optimizing the combustion process, or by exhaust gas aftertreatment. Optimizing the combustion process is the primary measure, and exhaust gas aftertreatment the secondary measure of reducing methane slip. Further optimization of the combustion process is the present medium of reducing methane slip because the secondary measures are not currently available for lean burn gas engines. Methane slip cannot be completely mitigated by primary measures because perfect combustion is never fully achieved, and crevices cannot be completely removed. However, a more efficient combustion could be achieved with, for example, hydrogen-methane fuel blends.^{120,121,122}

Most secondary exhaust gas aftertreatment options are not feasible for methane slip abatement yet. Many technical challenges are still to be overcome before the measures can be applied effectively.¹²³

¹¹⁷ MAN

¹¹⁸ EUROMOT, 2012

¹¹⁹ Wärtsilä, 2020

¹²⁰ MAN

¹²¹ EUROMOT, 2012

¹²² Wärtsilä, 2020

¹²³ Wärtsilä, 2020

Oxidation catalysts are not suitable for lean burn gas engines today. Catalyst regeneration and high operating temperatures oppose challenges for lean burn gas engine applications.¹²⁴

Afterburner is not a viable option for exhaust gas aftertreatment, either. While methane is destructed in over 800 Celsius degrees, the amount of additional fuel needed to heat up the flue gas will cause more GHG emissions than what can be abated via the afterburner.¹²⁵

Recuperative thermal oxidizers are only suitable for constant operation applications. They have a high hydrocarbon abatement potential, but they are very big, heavy, expensive, and the oxidizers need an external heat source.¹²⁶

2.2 Liquid Biofuels

Biofuels can be harnessed to decarbonize various sectors, such as transport, energy, and chemical industry. Liquid biofuels include FAME, HVO, crude bio-oils, bioethanol, and bio-methanol, among other bio-based fuels. The advantage of biofuels is that they contain renewable carbon. The need for carbon cannot be fully eliminated in all sectors, and in these instances bio-based components offer a great sustainable pathway. Long-distance shipping, for example, is a hard-to-abate sector that could be decarbonized with liquid biofuels. Bio-based alternatives of diesel are compatible with existing shipping fleet, as well as land-based engine plants.¹²⁷

The carbon content of biofuel is obtained from the air through photosynthesis. During the photosynthesis of plants and trees, carbon dioxide is absorbed from

¹²⁴ EUROMOT, 2012

¹²⁵ EUROMOT, 2012

¹²⁶ EUROMOT, 2012

¹²⁷ IEA-ETSAP, IRENA, 2013

the atmosphere for plant growth. The carbon dioxide that is released from burning biofuels essentially puts the same carbon dioxide back into the atmosphere that was taken out during photosynthesis, and thus the carbon dioxide release is not accounted towards climate change.^{128,129} In short, biofuels contain carbon, so their combustion releases carbon dioxide, like all carbon containing fuels. The source of carbon determines whether the carbon dioxide emitted puts additional GHG emissions into the atmosphere or not. Biofuel combustion results in negative emissions if it is coupled with carbon capture and storage, where the sequestered carbon dioxide is stored instead of released back into the atmosphere during biofuel combustion.¹³⁰

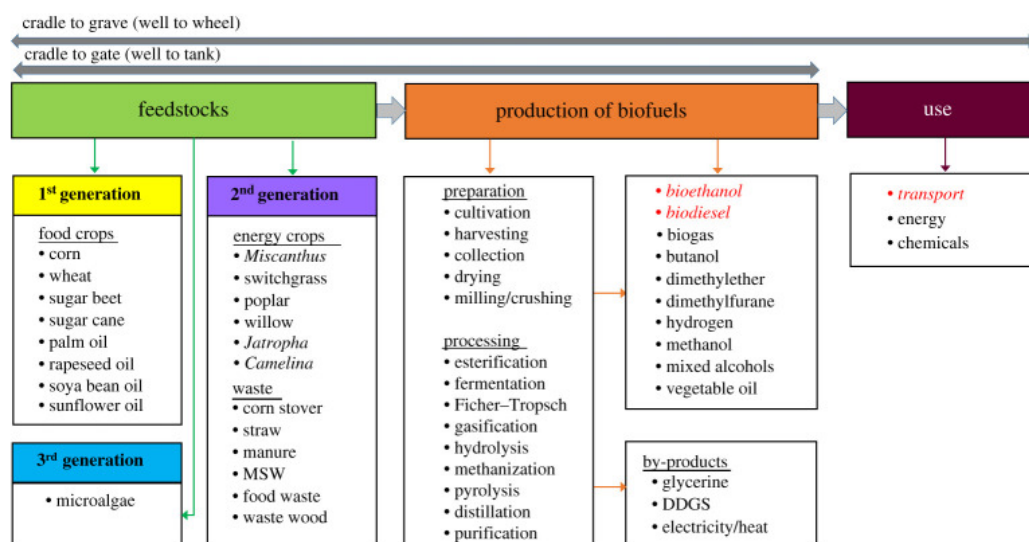


Figure 12. An overview of feedstocks and production processes for different biofuels¹³¹

Biofuels' life cycle GHG emissions originate from cultivation, transport, processing, distribution, and final use. As discussed previously, the carbon dioxide emissions

¹²⁸ IEA-ETSAP, IRENA, 2013

¹²⁹ Bioenergia

¹³⁰ Neste, 2020

¹³¹ Jeswani, Chilvers, and Azapagic, 2020

from combustion are considered zero. Cultivation and related emissions cover actions of collection, storage, drying, as well as fertilizers and other products applied to the cultivation process.¹³² The biggest sources of emissions are land-use, fertilizers, as well as fossil fuel powered transport and processing. Land-use change, and fertilizer needs can be altered by feedstock selection. GHG emissions could be further decreased by using renewable energy in processing.¹³³

2.2.1 Feedstocks

Conventional biofuels, also referred to as first-generation biofuels, use food and animal feed crops as feedstock.¹³⁴ Advanced biofuels, also referred to as second-, and third-generation biofuels, utilize non-food feedstocks. First-generation biofuels emit more GHG emissions than second-generation biofuels because food crop feedstocks lead to higher fertilizer and land-use emissions compared to other feedstocks of biofuel, like waste and residues.¹³⁵

First-generation biofuels cause land-use changes because deforestation can be initiated by the increased demand for biofuels. Forests act as a sink of carbon dioxide. In addition to lost carbon sinks, a large quantity of carbon dioxide is released to the atmosphere from soil and plant biomass during deforestation. Because first-generation biofuels use food feedstocks, biofuel and food are in competition of cultivation land. This not only leads to land-use change, but increased food prices as well.^{136,137}

¹³² European Union, 2018

¹³³ Arguelles-Arguelles, Amezcua-Allieri, and Ramírez-Verduzco, 2021

¹³⁴ Jeswani, Chilvers, and Azapagic, 2020

¹³⁵ Jeswani, Chilvers, and Azapagic, 2020

¹³⁶ European Environment Agency, 2021

¹³⁷ Jeswani, Chilvers, and Azapagic, 2020

Additional cultivation GHG emissions stem from nitrous oxide emissions caused by fertilizer usage. Fertilizer needs are high for first-generation biofuels as an unavoidable source of nutrients for plant growth. Energy crops, which are second-generation biofuel feedstocks, commonly use fertilizers only for the initial planting of crops, minimizing the fertilizer usage for the duration of cultivation.¹³⁸

Advanced biofuels, also referred to as second-, and third-generation biofuels, utilize non-food feedstocks. Second-generation feedstocks include energy crops, agricultural and forest residues, and waste, such as used cooking oil and municipal solid waste.¹³⁹ Advanced biofuels do not cause as much land use change related GHG emissions as conventional biofuels, because they can often be cultivated in land that has no agricultural or industrial value. Switchgrass, willow, and miscanthus, for example, can be cultivated in lands that are unsuited for food cultivation. Using waste and residues have even greater potential of reducing GHG emissions in terms of fertilizer and land-use when they do not have other potential end-uses.^{140,141} One of the largest producers of renewable diesel, Neste uses almost exclusively waste and residues as their feedstock. Neste has told that their biofuel typically reduces GHG emissions by 90 per cent compared to fossil fuel.^{142,143}

Third-generation biofuel uses algae as feedstock. The third-generation biofuel production is energy-intensive at the moment, and thus, emission-intensive as well if non-renewable energy sources are used for their production. The production yields low amounts of algae, and the energy demand for their cultivation, harvesting and drying is high, resulting in higher emissions compared to fossil fuels. The

¹³⁸ Jeswani, Chilvers, and Azapagic, 2020

¹³⁹ Jeswani, Chilvers, and Azapagic, 2020

¹⁴⁰ Chen, 2021

¹⁴¹ Environmental Protection Agency, 2021

¹⁴² Lassila, 2021

¹⁴³ Neste

production pathway of third-generation biofuels needs to be improved before commercial utilization.¹⁴⁴

2.2.2 Biodiesel

Diesel can be alternatively produced from fats, oils, and alcohols. These alternative diesels are referred to as bio- or renewable diesel. The difference between the two, is that renewable diesel production does not involve esters. Both bio- and renewable diesel can be produced from the same feedstocks. While biodiesel is commonly produced via transesterification, renewable diesel can be produced by hydrotreatment, or other alternative pathways. Renewable diesel is more stable than biodiesel. This chapter discusses biodiesel and related emissions.¹⁴⁵

Biodiesel is also referred to as fatty acid methyl esters, FAME. Biodiesel is made from vegetable oils but can be obtained using other feedstocks as well. Transesterification is the most common pathway of producing biofuel. The feedstock of choice reacts with alcohol, typically methanol, in the presence of a catalyst, to produce biodiesel and glycerine via transesterification.

Methanol used in the production of biodiesel is obtained from natural gas via SMR. The SMR process is explained in an upcoming chapter in conjunction with hydrogen. Other pathways of obtaining methanol are being explored, but for the time being the methanol used in the production is of fossil origin. The use of methanol increases the GHG emissions of biodiesel production.

FAME has a lower heating value than conventional diesel. Thus, the fuel consumption increases when using FAME. Conventional diesel has a higher combustion efficiency than biodiesel. Thus, conventional diesel results in lower carbon dioxide

¹⁴⁴ Jeswani, Chilvers, and Azapagic, 2020

¹⁴⁵ Van Gerpen, Shanks, Pruszko, Clements, & Knothe, 2004

emissions compared to FAME, especially under low load conditions. Biodiesel contains oxygen, so with high loads and rich air-fuel mixtures carbon dioxide formation is reduced due to enhanced combustion efficiency. In short, biodiesel releases more carbon dioxide under low loads compared to conventional diesel but operating on high loads shows that biodiesel creates less carbon dioxide than conventional diesel.¹⁴⁶

Biodiesel produced from sunflower oil is estimated to grant a 52 per cent reduction (typical value) in life cycle GHG emissions compared to fossil fuel. The estimation excludes land-use change emissions, assuming them to be zero. The corresponding reductions for different feedstocks are 50% for soybean, 84% for waste cooking oil, and 78% for animal fats. In EU the emission reduction from biofuel and bioliquid life cycle GHG emissions compared to fossil fuels needs to exceed 65 per cent for new production facilities in accordance with RED in order to contribute to Union targets of renewable energy shares. Based on these estimations, none of the first-generation oil crop feedstocks meet the limit. Animal fats and waste cooking oil would be the only viable feedstocks for biodiesel production in the EU for new production facilities.¹⁴⁷

2.2.3 Hydrotreated Vegetable Oil

HVO is a form of renewable diesel. HVO means hydrotreated vegetable oil, but unlike the name suggests, HVO can utilize feedstocks beyond vegetable oil. Alternative feedstocks of HVO include waste and residue fats and oils. Unlike biodiesel, HVO does not contain oxygen. Oxygen is removed from vegetable oil or animal fats using hydrogen. The term 'hydrotreatment' comes from the process of removing oxygen with hydrogen. Hydrotreatment essentially alludes to the fact that the

¹⁴⁶ Valente, da Silva, Pasa, Belchior, Sodré, 2010

¹⁴⁷ European Union, 2018/2001 Directive

feedstock reacts with hydrogen to produce fuel. The processing results in hydrocarbons which resemble the components of conventional diesel.¹⁴⁸

Hydrogen is produced from natural gas via SMR. Greener production pathways of hydrogen are not available on an industrial scale yet. The hydrogen utilized in the production of HVO increases its' life cycle GHG emissions. As discussed before, the production of biofuel requires methanol, which is also obtained from natural gas. The amount of natural gas required to produce FAME and HVO is almost the same for the two if they are produced from the same feedstock. Suggested GHG emissions of HVO produced from rapeseed oil is 44 gCO₂eq/MJ. The GHG emissions for FAME using the same feedstock of rapeseed oil would equate 53 gCO₂eq/MJ.¹⁴⁹

HVO can be blended with conventional diesel in any desired ratio. HVO is compliant with diesel fuel specifications even in its' pure form in the EU. FAME, on the other hand, has different properties than hydrocarbons, and can't be blended in the same manner.¹⁵⁰

HVO production from rapeseed oil is estimated to result in 47 per cent reduction (typical value) in life cycle GHG emissions compared to fossil fuel. The estimation does not take land-use change into account. The corresponding percentages for sunflower feedstock is 54%, soybean 51%, animal fats 77%, and waste cooking oil 83%. In EU the emission reduction from biofuel and bioliquid life cycle GHG emissions compared to fossil fuels needs to exceed 65 per cent for new production facilities to be in accordance with RED and contribute to Union targets of renewable energy shares. Based on these estimations, none of the first-generation oil crop feedstocks meet the set limit. Animal fats and waste cooking oil would be the

¹⁴⁸ Neste, 2016

¹⁴⁹ Neste, 2016

¹⁵⁰ Neste, 2020

only viable feedstocks for HVO production in the EU for new production facilities.¹⁵¹

2.2.4 Bioethanol

In addition to bio-based substitutes for diesel, there are bio-based alternatives for other hydrocarbons as well. Bioethanol, for example, is an already commercially used substitute for gasoline.

Bioethanol is typically produced from food feedstocks. As discussed previously, this leads to emissions from land-use change and fertilizer usage. Second-generation feedstocks are being explored in the field of bioethanol production, which would decrease the emissions associated with first-generation feedstocks. Sugar-cane is a favourable feedstock for first-generation bioethanol, because it has lower requirements for fertilizer and pesticides, high yield of crops, and electricity is often co-produced in bioethanol refineries.¹⁵²

Bioethanol is produced via enzyme and bacteria breakdown of fermentable sugars in a biochemical process. The processing of bioethanol is done in steps of pretreatment, hydrolysis, fermentation, and ethanol recovery.¹⁵³ Bioethanol production has increased in energy efficiency over the years due to improved farming techniques, fertilizer and pesticide use, and processing.¹⁵⁴

Ethanol produced from sugar beet with natural gas used as a process fuel in a conventional boiler is estimated to result in a 59-73 per cent reduction (typical value) in life cycle GHG emissions compared to fossil fuel. The corresponding percentage for sugar cane ethanol is 70. The estimations do not account for land-use change.

¹⁵¹ European Union, 2018/2001 Directive

¹⁵² Jeswani, Chilvers, and Azapagic, 2020

¹⁵³ Edeh, 2020

¹⁵⁴ The U.S. Department of Energy

In EU the emission reduction from biofuel and bioliquid life cycle GHG emissions compared to fossil fuels needs to exceed 65 per cent for new production facilities in accordance with RED and to contribute to Union targets of renewable energy shares. Sugar beet and sugarcane feedstocks would be within the RED limits, if the cultivation does not lead to land-use changes. Wheat straw, which is a non-food feedstock of biofuel, would grant an 85 per cent GHG emission reduction compared to fossil fuel. Wheat straw is not a widely used feedstock for ethanol production yet.^{155,156}

2.3 Biogas

Biogas is mainly produced in a process called anaerobic digestion. Anaerobic digestion uses feedstocks of organic matter, for example sewage wastewater sludge, manure, biodegradable waste, and energy crops.¹⁵⁷

Landfill waste can also be used for obtaining biogas. This gas is called landfill gas. Landfill gas has a significant GHG emission reduction potential, because if the waste in landfills is left to decompose without utilizing it for gas production, the methane and carbon dioxide emissions occurring during waste decomposition are emitted straight to the atmosphere. The same can be said for manure. When manure is left to decompose without applying proper manure management practices, the resulting emissions are emitted to the atmosphere.¹⁵⁸

¹⁵⁵ Neste, 2020

¹⁵⁶ European Union, 2018/2001 Directive

¹⁵⁷ Zhou, Swidler, Searle, and Baldino, 2021

¹⁵⁸ Zhou, Swidler, Searle, and Baldino, 2021

Biomethane, also referred to as renewable natural gas, is an almost pure methane gas that can be produced in the gasification process of solid biomass, or by refining biogas. The most common way of producing biomethane is by refining biogas.¹⁵⁹

Gasification pathway to biomethane is utilized less often than biogas refining, and at smaller scales. Potential reasons for the small-scale production today include issues in achieving stable operation, costs, and by-product treatment.¹⁶⁰

Biogas is refined to biomethane by removing carbon dioxide, other impurities, and moisture from biogas. Raw biogas typically contains 50-70 per cent methane, with most of the rest being carbon dioxide. This means that the production of biomethane comes with a by-product of carbon dioxide. The by-product can be used in agriculture and industry, but it could also be reacted with hydrogen to produce more methane and other synthetic fuels. Biomethane production could be made carbon dioxide negative if carbon capture and storage was utilized, but storage safety, leakage, and injection are still under research and development. For this reason, utilization of the co-produced carbon dioxide is preferred over storage.^{161,162}

Biomethane has the same heating value as natural gas, and it is often refined to exceed the purity and quality of natural gas. Biomethane can be used in the existing natural gas pipelines without modifications and can reach all the same end users: buildings, industrial facilities, power plants.¹⁶³

Natural gas results in higher GHG emissions than biomethane. Even though the combustion of biomethane results in same carbon dioxide emissions as natural

¹⁵⁹ International Energy Agency, 2020

¹⁶⁰ International Energy Agency, 2020

¹⁶¹ Kelemen, Benson, Pilorgé, Psarras, and Wilcox, 2019

¹⁶² International Energy Agency, 2020

¹⁶³ Zhou, Swidler, Searle, and Baldino, 2021

gas, the release does not add to climate change, because the carbon contained in biomethane is essentially put back into the atmosphere during combustion, where it originally came from during photosynthesis. However, methane emissions from the combustion are added to the total GHG emissions of the fuel.¹⁶⁴

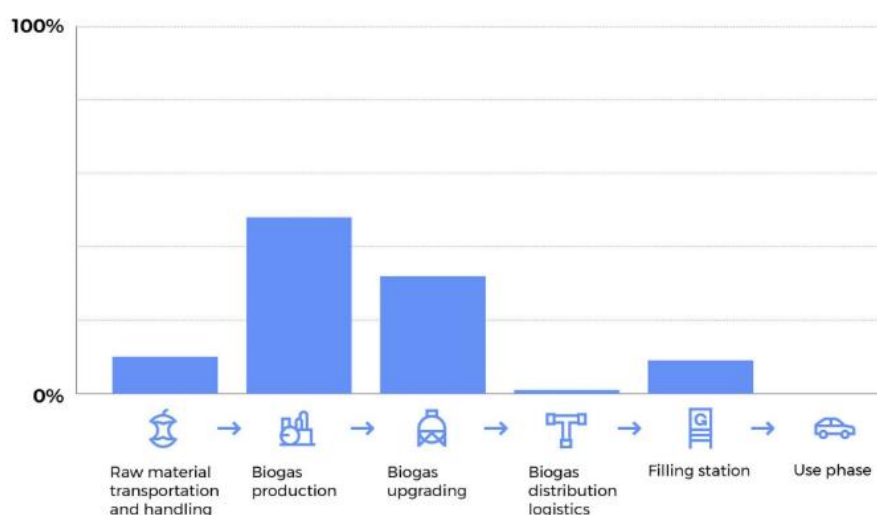


Figure 13. Greenhouse gas emissions over the entire life cycle of biogas (well to wheel, WTW) at the various stages of production¹⁶⁵

The Figure 13 above illustrates an example of the biogas' life cycle emissions. The emissions stem from transportation, production, upgrading, distribution, and end use. As established before, the end use carbon dioxide emissions are equal to zero. The transport and collection of biomass feedstock emissions essentially cover the fossil fuel used for transport, and methane leakage.¹⁶⁶

Methane leakage occurs during anaerobic digestion and biogas refining for all biogas feedstocks, for example wastewater sludge, landfill gas, and manure. In addition to methane leakage from anaerobic digestion and biogas refining, methane

¹⁶⁴ International Energy Agency, 2020

¹⁶⁵ Gasum, 2021

¹⁶⁶ Gasum, 2021

leakage occurs in waste feedstock transport and storage.¹⁶⁷ However, the most substantial methane leakages occur during the production and refining stages. The energy required for production and refining add onto the emissions from these activities, making production and refining the most GHG emission intensive processes in the whole life cycle.¹⁶⁸

Methane leakage emissions from biomethane production are highly variable and hard to quantify. Depending on the degree of methane leakage, the achieved GHG reductions can be significant, or the GHGs might surpass the emission intensity of natural gas.¹⁶⁹

Biomethane transmission via pipeline and injection to the gas grid cause emissions similar to natural gas. The fugitive methane emissions from gas grid are emitted to the atmosphere in the same manner as natural gas' fugitive emissions.¹⁷⁰

2.4 Hydrogen

Hydrogen can be produced from a wide variety of energy sources. Nowadays the most common energy source of hydrogen production is fossil fuels. Six per cent of natural gas and two per cent of coal are used to produce hydrogen globally. The hydrogen production emits 830 mega tonnes of carbon dioxide emissions annually.¹⁷¹

Hydrogen is mainly used in the chemical and refining industry. The annual demand for hydrogen reached 90 mega tonnes in 2020. Oil refining sector used 40 mega tonnes of the produced hydrogen, and most of the rest was used in the chemical

¹⁶⁷ Zhou, Swidler, Searle, and Baldino, 2021

¹⁶⁸ Gasum, 2021

¹⁶⁹ Zhou, Swidler, Searle, and Baldino, 2021

¹⁷⁰ Gasum, 2021

¹⁷¹ IRENA, 2018

industry. Almost 75 per cent of chemical industry hydrogen was used to produce ammonia, with the rest being used to produce methanol. Industry sector's iron and steel production had a five mega tonne demand for hydrogen. The utilization of hydrogen as a transport fuel is very low at the moment. The demand for hydrogen is estimated to grow by over two-fold in a decade. While industry is going to use more hydrogen, new purposes of hydrogen will emerge. These include grid injection, power, transport, buildings, synthetic fuels, and ammonia production for fuel. Hydrogen can be harnessed to decarbonize hard-to-abate sectors.¹⁷²

Low-carbon hydrogen can be produced via electrolysis when the process is powered by nuclear or renewable energy. Hydrogen produced using nuclear is called pink hydrogen, and hydrogen produced from renewable energy is called green hydrogen.^{173,174}

Wind and solar electricity are non-dispatchable renewable energy sources. The electric grid must be always balanced. In other words, the demand and supply must be equal at all times. If there is not enough electricity demand, and the surplus electricity cannot be stored, a curtailment of the renewable electricity production must be carried out. Producing hydrogen from this surplus renewable energy could present an excellent storage alternative. This way the renewable energy can be stored in the produced hydrogen, and can then be used to stabilize the grid when intermittent renewable energy is not available, and additional balancing thermal power production is needed to meet the energy demand.^{175,176}

¹⁷² International Energy Agency, 2021

¹⁷³ IRENA, 2018

¹⁷⁴ Methanol Institute, 2018

¹⁷⁵ IRENA, 2018

¹⁷⁶ Methanol Institute, 2018

Thus, hydrogen can enable the mass deployment of renewables. The production of green hydrogen through electrolysis requires large production capacities of renewable energy. Ramping up both hydrogen and renewable power production is important for reaching net zero GHG emission targets. The deployment of low-carbon hydrogen in the large scale requires further technological advancements of fuel cells, electrolyzers, and CCS.¹⁷⁷

Hydrogen combustion does not lead to direct carbon dioxide emissions since hydrogen does not contain any carbon. The complete combustion of hydrogen creates water vapor as its' only by-product.

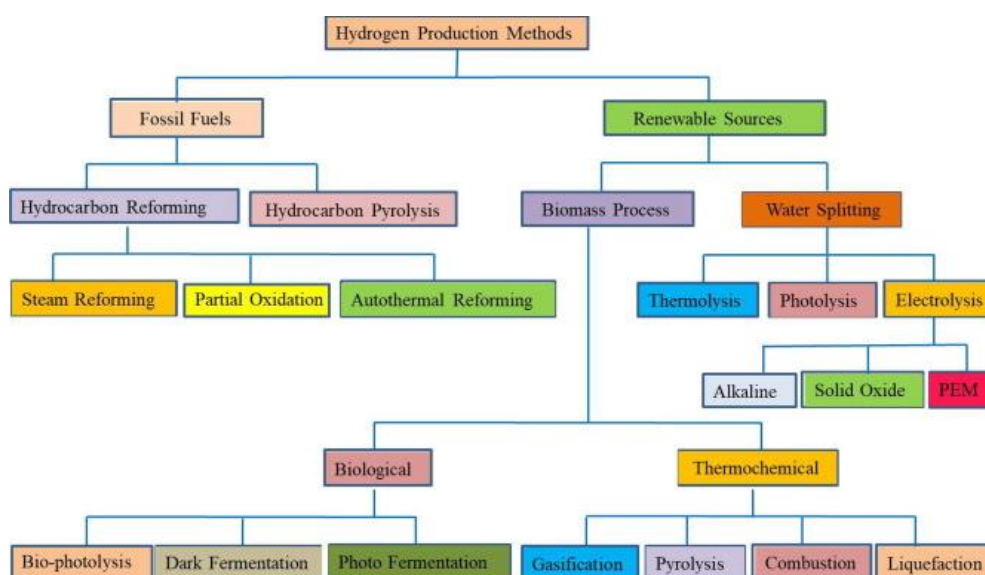


Figure 14. Various Hydrogen Production Methods¹⁷⁸

There are multiple pathways of producing hydrogen. The emissions from the most relevant production pathways and feedstocks are discussed in detail in the following sections. The focus is on natural gas, biomethane, and renewable energy pathways.

¹⁷⁷ International Energy Agency, 2022

¹⁷⁸ Kumar, and Himabindu, 2019

2.4.1 Hydrogen Production from Methane

Steam methane reforming (SMR) is the cheapest and most common technology of producing hydrogen. The SMR process can use natural gas and biomethane as feedstocks due to their identical properties.

Hydrogen production via SMR starts with a methane and steam reaction in a reformer. The reaction creates carbon monoxide and hydrogen. The created carbon monoxide goes through a water-gas shift to produce carbon dioxide and more hydrogen. The product of hydrogen and carbon dioxide is called syngas. After this, the pressure-swing adsorption process is applied to the syngas to separate the hydrogen from the syngas. The remaining gas after hydrogen has been removed from the syngas is called tail gas. The tail gas is reused in the process by feeding it back into the reformer.¹⁷⁹

The total methane consumption of SMR constitutes of methane used as feedstock and process fuel. Methane feedstock generally covers 60 per cent of the total fuel consumption. The remaining 40 per cent is used as process fuel.¹⁸⁰

¹⁷⁹ Zhou, Swidler, Searle, and Baldino, 2021

¹⁸⁰ Zhou, Swidler, Searle, and Baldino, 2021

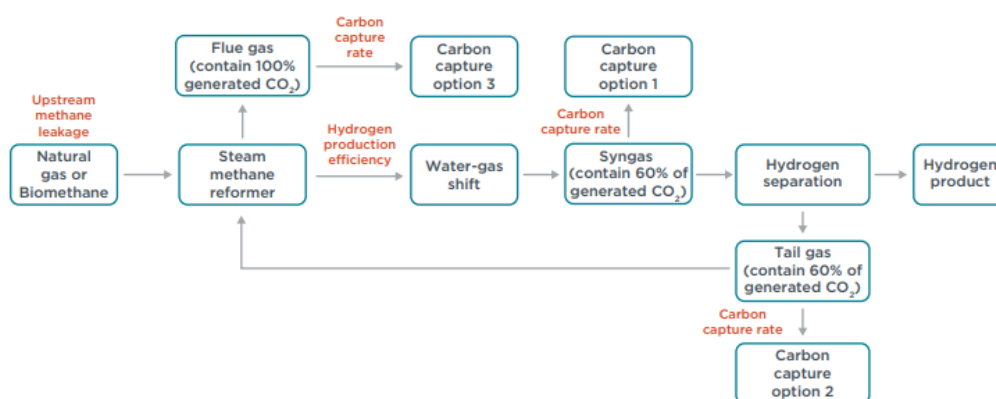


Figure 15. Simplified scheme of hydrogen production¹⁸¹

One kilogram of hydrogen produced via SMR co-produces about 8 kilograms of carbon dioxide. The carbon dioxide emissions produced during SMR are contained in flue gases, which are typically released to the atmosphere. However, the carbon dioxide content of the flue gases can be sequestered to, for example, depleted natural gas reservoirs utilizing carbon capture and storage, CCS.¹⁸²

The current use of CCS captures only half of the total carbon dioxide emissions generated. The current capture rate does not result in the required GHG reductions to deem hydrogen production low-carbon. The carbon capture rate needs to be improved to achieve satisfactory reductions. Economical constraints prohibit the full capture of generated carbon dioxide. CCS is very expensive for the time being, and it represents a large portion of the cost of hydrogen production when it is adopted. A carbon capture rate of 50 per cent does not equate 50 per cent of total GHG emissions reduced. The CCS process requires energy, which results in additional GHG emissions.^{183,184}

¹⁸¹ Zhou, Swidler, Searle, and Baldino, 2021

¹⁸² CIMAC, 2020

¹⁸³ Zhou, Swidler, Searle, and Baldino, 2021

¹⁸⁴ Hydrogen Council, 2021

Deploying CCS decreases the energy efficiency of an SMR plant by about 14 per cent due to energy requirements of activities such as increasing the heat in the reformer, operating the carbon capture unit, and compressing the captured carbon dioxide.¹⁸⁵ The energy requirements of CCS increase the natural gas consumption of the plant. Accommodating some of the energy needs with renewable energy could further reduce emissions.¹⁸⁶

As discussed in a previous chapter, fugitive emissions of methane are present in up-, and midstream activities of the natural gas supply chain. Addressing these emissions has a great abatement potential.

Another way of producing hydrogen from methane is autothermal reforming (ATR). Life cycle emissions of ATR are not fully researched yet, but ATR could achieve higher carbon capture rates than SMR. Steam methane reforming has three carbon dioxide streams: the flue gas outlet, syngas outlet, and the tail gas outlet. ATR has only one concentrated stream of carbon dioxide. In the case of ATR, more carbon dioxide could be captured with relative ease compared to SMR. However, combining CCS with ATR requires more electricity, especially when obtaining high capture rates. The high electricity consumption reduces the climate benefits when the electricity used for CCS is non-renewable. ATR is not expected to be largely deployed for hydrogen production.¹⁸⁷

Hydrogen can be produced from methane via methane pyrolysis as well. Methane pyrolysis would result in solid carbon as its' only by-product, eliminating the need for CCS. Solid carbon is easier to dispose of compared to gaseous or liquid carbon dioxide. The technology is still under development, and it is mostly utilized at small

¹⁸⁵ Zhou, Swidler, Searle, and Baldino, 2021

¹⁸⁶ CIMAC, 2020

¹⁸⁷ Zhou, Swidler, Searle, and Baldino, 2021

scales today, but the pathway is an attractive alternative for obtaining blue hydrogen.¹⁸⁸

TABLE 3 - PYROLYSIS AND STEAM METHANE REFORMING

Process	Efficiency in %	Year / time frame	TRL	Source
SMR	70	Today	9	[6]
Pyrolysis	55	Today	Low-medium*	[7], [10]
SMR / Pyrolysis + CCS	56-65	Today	~7	[6], [10]

*depending on the type of pyrolysis covers different stages from R&D to commercially available processes

Figure 16. Pyrolysis and steam methane reforming, TRL = Technology Readiness Level¹⁸⁹

Combining CCS with SMR might be the transition phase production method of hydrogen in the absence of required electrolysis facilities and renewable energy. The efficiency of SMR coupled with CCS is estimated to be 56 to 65 per cent today (see Figure 16). The use of CCS decreases the efficiency of the SMR plant by about 14 per cent.^{190,191,192}

2.4.2 Hydrogen Production from Renewable Energy

Green hydrogen is produced by splitting water into hydrogen and oxygen using preferably renewable electricity in a process called water electrolysis. Grid electricity is not recommended for hydrogen production due to its' GHG emission intensity. Hydrogen Council states that hydrogen produced through electrolysis powered by EU's 2030 grid electricity would result in more emissions compared to hydrogen production through SMR. If the electricity used to produce hydrogen via electrolysis had the global average carbon intensity of today's grid electricity of 475 gCO₂/kWh, the hydrogen produced would exceed the emissions of unabated

¹⁸⁸ International Energy Agency, 2021

¹⁸⁹ CIMAC, 2020

¹⁹⁰ CIMAC, 2020

¹⁹¹ Intergovernmental Panel on Climate Change

¹⁹² International Energy Agency, 2022

natural gas SMR produced hydrogen by threefold. The main driver of grid electricity's emission intensiveness is the share of coal in electricity production. Grid electricity of 2030 is not recommended to be used for hydrogen production in REDII. Grid electricity would be suitable for hydrogen production in 2050, if the electricity supply is decarbonized by that time.^{193,194}

Water electrolysis powered by nuclear and renewable energy have the potential of producing hydrogen with very low carbon emissions. Solar would result in slightly higher emissions compared to other renewables and nuclear, due to grid electricity powered manufacturing of solar panels, which increases their life cycle GHG emissions. Electrolysis powered by nuclear can obtain very low GHG emissions. However, the production also creates 0,115g of radioactive waste per kilogram of hydrogen. By 2030 the usage of grid electricity for electrolysis is going to result in most emissions out of all the hydrogen production pathways (see Figure 17).¹⁹⁵

¹⁹³ Hydrogen Council, 2021

¹⁹⁴ International Energy Agency, 2022

¹⁹⁵ Hydrogen Council, 2021

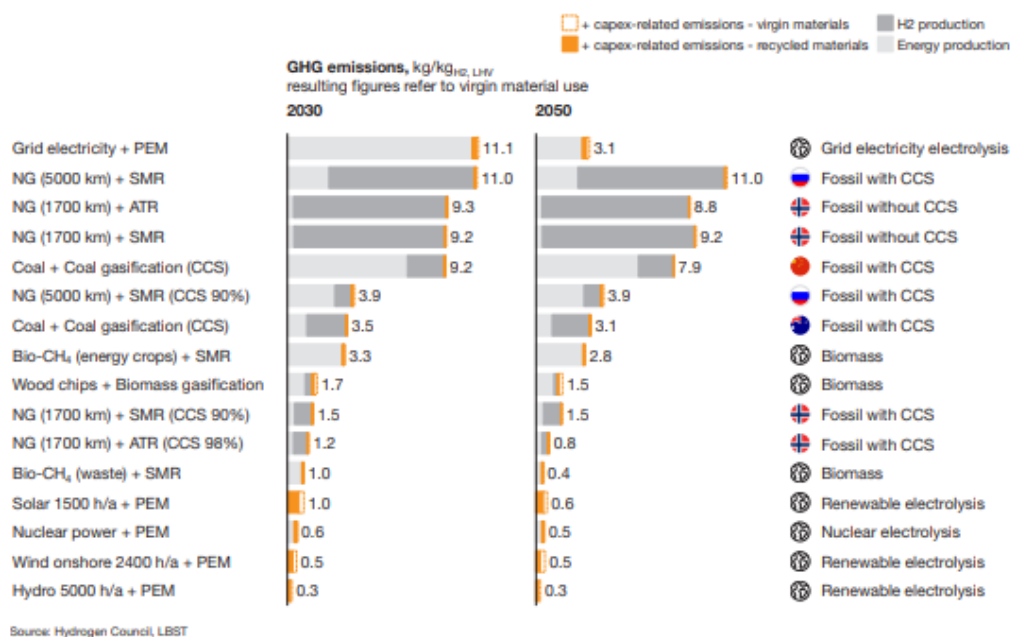


Figure 17. Carbon-equivalent emissions by hydrogen production pathways, 2030 and 2050¹⁹⁶

Nine kilograms of water is needed to produce one kilogram of hydrogen via electrolysis, except for nuclear power. Electrolysis powered by nuclear demands 270 kilograms of water per one kilogram of hydrogen. Large-scale hydrogen production facilities consume a lot of water. Regions that have a limited amount of water to spare, would preferably use sea water. In this case desalination facilities are needed. The electricity requirement of desalination is negligible compared to the electrolysis process itself. Hydrogen production from biogas (made from energy crops, for example) can be up to a thousand times more water intensive compared to other pathways.¹⁹⁷

¹⁹⁶ Hydrogen Council, 2021

¹⁹⁷ Hydrogen Council, 2021

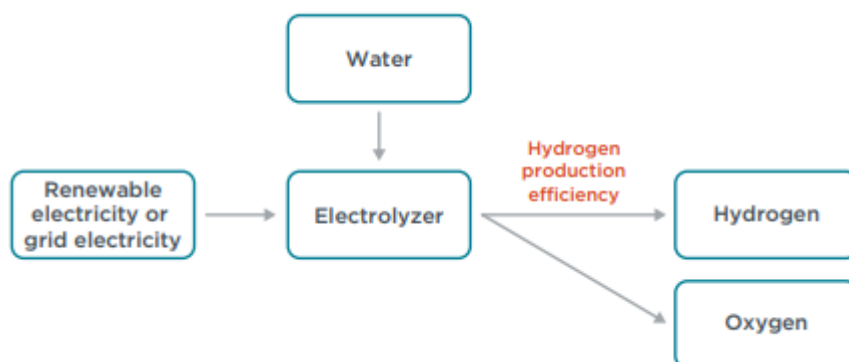


Figure 18. Simplified scheme of hydrogen production¹⁹⁸

An electrolyzer is a device that splits water into hydrogen and oxygen with electricity. The three main electrolyzer types include alkaline, Polymer electrolyte membrane (PEM), and solid oxide electrolyzer cells (SOEC).

Alkaline is the most common electrolyzer type used in hydrogen production via electrolysis today. Alkaline electrolyzers are the most inexpensive and most advanced of the technologies, but they might fall short on efficiency compared to the other two. Alkaline electrolyzers perform well in continuous operation.^{199,200}

Polymer electrolyte membrane, or also called proton exchange membrane (PEM) electrolyzers have the potential of exceeding alkaline electrolyzers in efficiency (see Figure 19). The low temperature electrolyzers, alkaline and PEM, have an average efficiency of 65 per cent today. PEMs could offer a better operation of electrolysis with renewable energy due to their flexibility and responsiveness compared to alkaline electrolyzers.^{201,202}

¹⁹⁸ Zhou, Swidler, Searle, and Baldino, 2021

¹⁹⁹ Zhou, Swidler, Searle, and Baldino, 2021

²⁰⁰ CIMAC, 2020

²⁰¹ Zhou, Swidler, Searle, and Baldino, 2021

²⁰² CIMAC, 2020

Solid oxide electrolyzer cells, SOECs, have a potential of exceeding PEMs in efficiency. The technology is still under development, but they could technically provide an efficiency of 80 to 90 per cent. While PEMs require platinum catalysts, SOECs do not require any rare raw materials to operate.^{203,204,205}

TABLE 2 - HYDROGEN PRODUCTION, PROCESS/PATHWAY EFFICIENCIES

Process	Pathway step	Efficiency in %	Year / time frame	Source
ALK-electrolysis	H ₂ Production	65	Today	[1]
		58	2025	[4], LHV
		53-69	2030	[1], [9]
		61	2050	[4], LHV
PEM-electrolysis	H ₂ Production	62-67	Today	[1]*, [2]**, [12] LHV
		58	2025	[4]*, LHV
		62.8 - 75.7	2030	[1]*, [9], [2]**, [12] LHV
		71-80	2050	[4]*, [12] LHV
SO-electrolysis	H ₂ Production	81	Today	[12] LHV
		77-92	2030	[1], [9], [12] LHV
		90	2050	[12]
Co-SO-electrolysis	H ₂ Production	81	2030	[1]
H ₂ liquefaction	Conversion	79.7	Today	[2]
		83.7	2030	[2]
H ₂ compression	Conversion	94	Today	[11]
LOHC	Hydrogenation	100	Today	[2]**
	Dehydrogenation / Unloading	70	Today	[2]
H ₂ (compr.700 bar) via PEM	Whole chain / pathway	58	2030	[4]
		65	2050	[4]
H ₂ (compressed 250 bar) via ALK/PEM	Whole chain / pathway	61	Today	[3]
		70	2050	[3]
H ₂ (liquified) via ALK/PEM	Whole chain / pathway	53	Today	[3]
		64	2050	[3]
H ₂ (liquified.) via PEM, incl. transport via ship	Whole chain / pathway	52.4	2020	[2]
		57.9	2030	[2]

Figure 19. Hydrogen production, process/pathway efficiencies²⁰⁶

²⁰³ Zhou, Swidler, Searle, and Baldino, 2021

²⁰⁴ CIMAC, 2020

²⁰⁵ CIMAC, 2020

²⁰⁶ CIMAC, 2020

In order to transport hydrogen, it needs to be liquefied, pressurized, or transported as liquid organic hydrogen carrier, LOHC. Liquefied hydrogen requires more electricity than compressed gaseous hydrogen. This is caused by the lower efficiency of the liquefaction process compared to compression.^{207,208}

Hydrogen sourced from renewables is also the backbone of zero carbon, net zero carbon, and low carbon fuels. The fuels include ammonia and other synthetic fuels. Synthetic fuels are produced from hydrogen with additional processing and adding carbon or nitrogen. The most significant factor of life cycle GHG emissions of the synthetic fuels is the origin of energy utilized in the production of these fuels. When comparing synthetic and fossil fuels, it is important to note that GHG emissions of synthetic fuels such as ammonia occur upstream, while the emissions of fossil fuels originate from the combustion process itself, with less emissions occurring upstream. The exception to this is low carbon synthetic fuels such as methanol, which need to source their carbon content from sequestered carbon dioxide to result in net zero combustion GHG emissions.²⁰⁹

The net zero production pathways of ammonia and methanol are discussed further in the following sections.

²⁰⁷ CIMAC, 2020

²⁰⁸ Zhou, Swidler, Searle, and Baldino, 2021

²⁰⁹ CIMAC, 2020

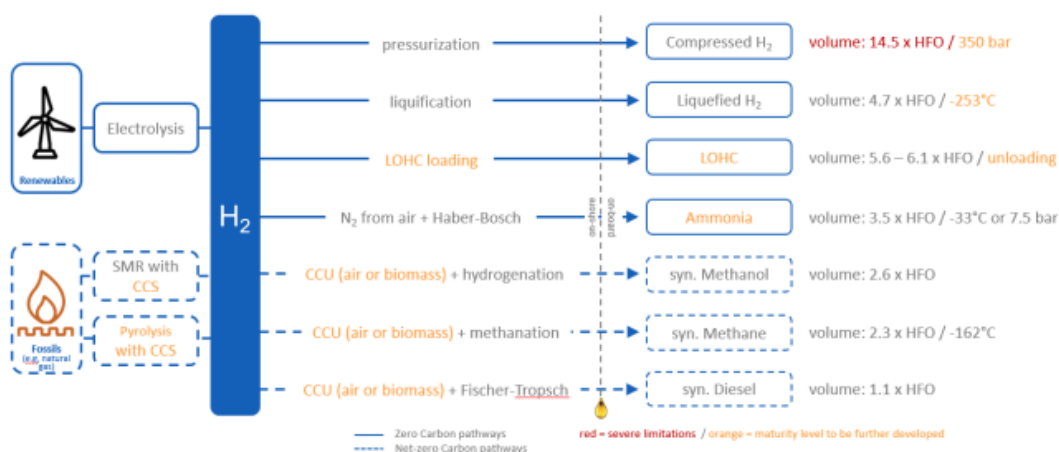


Figure 20. (Net) Zero carbon fuel production pathways (non-exhaustive); fossil pathways as transitional technologies²¹⁰

2.5 Ammonia

Nowadays ammonia is mainly used to produce fertilizers, but it can be combusted in fuel cells and internal combustion engines (ICE) to produce energy. Ammonia could provide a zero-carbon energy source, but it is not commercialized as a fuel yet. Ammonia is easy to produce, and the technology is mature. The combustion of ammonia might, however, result in additional nitrous oxide emissions, which is a powerful GHG.²¹¹

The current use of ammonia is almost exclusively limited to fertilizer usage. In the absence of green hydrogen, grey hydrogen is used in the production today, making ammonia synthesis one of the biggest carbon dioxide emitters of the chemical industry. Hydrogen is the largest contributor to ammonia's emissions. The preferred

²¹⁰ CIMAC, 2020

²¹¹ CIMAC, 2021

production pathway of hydrogen used in ammonia synthesis is electrolysis powered by renewable energy. Emissions from different hydrogen pathways were discussed in the previous chapter.^{212,213}

Ammonia is produced via the Haber-Bosch process from nitrogen and hydrogen in high temperatures and pressures with a catalyst. Cryogenic air separation is the most common way of obtaining the nitrogen needed in ammonia production. The Haber-Bosch process requires a lot of energy. Less energy requiring production methods are also explored, like solid-state-ammonia-synthesis.^{214,215}

Figure 1: Green ammonia production process

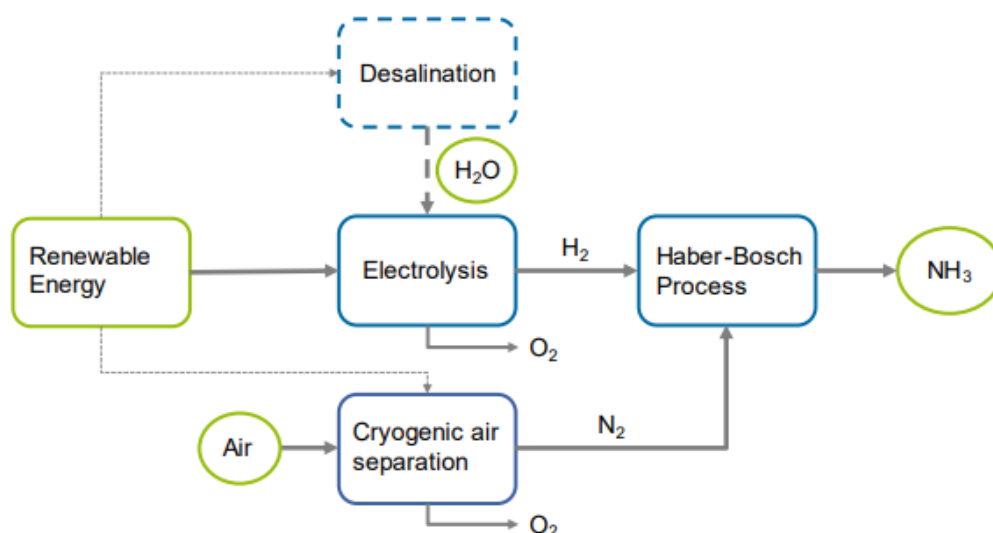


Figure 21. Green ammonia production process²¹⁶

The Haber-Bosch process is a mature technology, and thus the energy efficiency of the process has had time to develop. Even though the efficiency of the Haber-

²¹² CIMAC, 2020

²¹³ Oeko-institut, 2021

²¹⁴ CIMAC, 2020

²¹⁵ Oeko-institut, 2021

²¹⁶ Oeko-institut, 2021

Bosch process is hard to further improve, the emissions can be reduced by utilizing renewable energy to power the process. Replacing fossil energy with renewable energy can be carried out in each production step of ammonia to reduce life cycle GHG emissions.^{217,218} Thus, the emissions from the production of ammonia depend largely on the source of energy used within processing. Production emissions of ammonia can reach close to zero if powered by renewable energy. Powering the hydrogen production with renewable energy is the most significant way of bringing down the GHG emissions of ammonia.²¹⁹

TABLE 4 - AMMONIA PRODUCTION

Process	Efficiency in %	Year / time frame	Source
Air separation	71.25	Today	[11]
Haber-Bosch	73.4-81.8	Today	[11]
Whole process incl. ALK/PEM, cryogenic air separation, Haber-Bosch	52	Today	[3]
	60	2050	
Whole process incl. PEM, cryogenic air separation, Haber-Bosch, compression and transport via ship	47.7	2020	[2]
	52.4	2030	

Figure 22. Ammonia production²²⁰

As stated previously, ammonia production is already a well-established industrial process, and it has a satisfactory fuel pathway efficiency. The efficiency is brought down by the requirement of producing the hydrogen from renewable electricity. When the electrolysis production of hydrogen gets more efficient, so will ammonia production. Electrolyzer efficiencies are expected to improve in the future.^{221,222,223}

²¹⁷ CIMAC, 2020

²¹⁸ Oeko-institut, 2021

²¹⁹ Oeko-institut, 2021

²²⁰ CIMAC, 2020

²²¹ CIMAC, 2020

²²² Oeko-institut, 2021

²²³ CIMAC, 2020

The current efficiency of ammonia synthesis is 52 per cent, when electrolysis, cryogenic air separation, and the Haber-Bosch process are accounted for (see Figure 22).

2.5.1 Combustion Emissions

Ammonia can be combusted, for example, in a fuel cell or a reciprocating internal combustion engine (RICE). The choice of combustion technology affects the emissions.

Ammonia does not contain any carbon, and thus its' combustion does not lead to direct carbon dioxide emissions. If carbon-based fossil fuels are used as pilot fuel to ignite the ammonia for RICE combustion, carbon dioxide emissions will be emitted.²²⁴

The combustion of ammonia in RICE, however, results in ammonia slip, NO_x, and nitrous oxide emissions. Some means of controlling ammonia slip already exist. For example, ammonia slip catalysts have been developed for road transport.²²⁵

The bulk of nitrous oxide emissions are direct emissions from combustion. Higher combustion temperatures decrease nitrous oxide emissions and ammonia slip but increase NO_x emissions. Catalysts for the simultaneous removal of NO_x and nitrous oxide are available for emission reduction. The combustion process can be optimized to reduce resulting emissions as well.²²⁶

²²⁴ Oeko-institut, 2021

²²⁵ Oeko-institut, 2021

²²⁶ Oeko-institut, 2021

Ammonia could also lead to indirect nitrous oxide emissions if it leaks into soils or water, via bacteria induced denitrification. The amount of ammonia converted to nitrous oxide in soils and water is highly variable and difficult to estimate.²²⁷

Ammonia can be directly used in a solid oxide fuel cell, SOFC. Solid oxide fuel cells operate at high temperatures. SOFCs could lead to some minor NO_x emissions, but the emissions associated with the combustion are still uncertain due to lack of test data. SOFC is still under research for ammonia combustion. Fuel cells can reach high efficiencies, with an associated improvement in fuel consumption.²²⁸

2.6 Methanol

2.6.1 Synthetic Methanol

Synthetic fuels, also called electro-fuels or e-fuels, can be obtained by synthesizing hydrogen and carbon dioxide. The synthetic fuels include, for example, synthetic methanol, synthetic methane, synthetic diesel, synthetic petrol, and synthetic kerosene. Synthetic fuels can be used in existing infrastructure, engines, and heating systems. These fuels can fully replace conventional fossil fuels and can be blended with them in any desired ratio. This chapter discusses exclusively synthetic methanol.²²⁹

Methanol can be produced from a variety of sources and pathways. To name a few, grey methanol can be produced from SMR, blue methanol from SMR coupled with CCS, bio-methanol from biomass feedstocks, and e-methanol from captured

²²⁷ Oeko-institut, 2021

²²⁸ Oeko-institut, 2021

²²⁹ eFuel Alliance, 2021

carbon dioxide and renewable energy. Green methanol includes bio-methanol and e-methanol.²³⁰

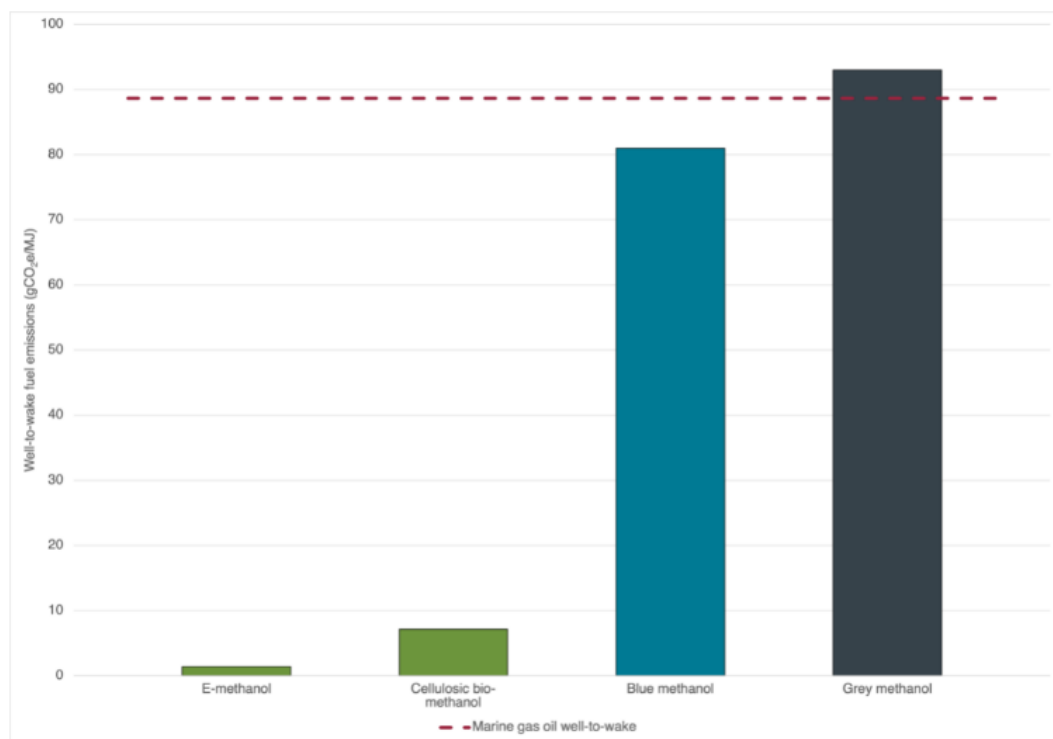


Figure 23. Well-to-Wake GHG emissions of methanol relative to Marine Gas Oil assuming a slow-speed ship²³¹

Grey methanol exceeds the emissions of marine gas oil, generating about 92 gCO₂eq/MJ emissions. Blue methanol, with a carbon capture rate of 90 per cent has high emissions as well, about 81 gCO₂eq/MJ. E-methanol has the potential of reaching close to zero emissions, while bio-methanol could achieve around 8 gCO₂eq/MJ emissions.²³²

The emissions of blue methanol and grey methanol are substantially higher than green methanol's. This is because the carbon dioxide emissions occurring during

²³⁰ Martin, 2021

²³¹ Martin, 2021

²³² Martin, 2021

the combustion of these fuels are not sequestered, and they are accounted towards the overall emissions. Because methanol is a carbon containing fuel, its' combustion results in carbon dioxide emissions. While hydrogen and ammonia, fuels that do not contain carbon, can benefit from the natural gas SMR coupled with CCS pathway, the same does not necessarily apply to carbon containing fuels, such as methanol, because they release carbon dioxide during combustion.^{233,234}

If the source of the carbon, in the case of synthetic methanol, is renewable (from biomass or direct air capture, DAC), the carbon dioxide released during combustion is not considered in the total emissions. This is because the carbon from air is put back into the atmosphere, avoiding the emitting of new carbon dioxide. The fuel would be considered net zero carbon if the source of the carbon dioxide is renewable, and the hydrogen is produced using renewable energy. When CCU is done in conjunction with fossil fuel combustion, the produced methanol is not considered net zero carbon, however, it would be considered low carbon. The use of captured carbon dioxide, in this case, would transfer the carbon dioxide emissions to another sector, not abate them. Bio-methanol will be discussed separately in an upcoming chapter. This chapter focuses on synthetic methanol.^{235,236}

Methanol synthesis is the most common pathway of producing synthetic methanol. Methanol synthesis is already a widely used industrial process. Hydrogen and carbon dioxide are synthesized into methanol during the process. The synthesis includes steps of producing syngas, producing crude-methanol, and conditioning.

²³³ Martin, 2021

²³⁴ Getting to Zero Coalition

²³⁵ Martin, 2021

²³⁶ Getting to Zero Coalition

The production technology has a lot of steps, and advancing this technology is under research. Direct methanol synthesis would allow skipping the first step of producing syngas.²³⁷

Despite the current interest in removing steps from methanol synthesis, the process is quite mature. It has an efficiency of about 80 per cent today. When the methanol synthesis known today is considered with its' three steps, including hydrogen electrolysis and direct air capture, the efficiency of the whole fuel pathway is estimated at a hair over 40 per cent. The conclusion is that electrolysis and DAC have dissatisfactory efficiencies.²³⁸

DAC requires a lot of energy, and it is not a mature technology yet. Further developments on DAC are needed for its' commercial utilization. Capturing 1 kg of carbon dioxide from ambient air would require around 1,75 kWh of thermal heat and 0,25 kWh of electrical energy. The numbers are bound to decrease a little bit over the decade.²³⁹

2.6.2 Bio-methanol

Methanol is usually produced from natural gas, but it can be obtained from organic sources, such as biogas, biomethane, biomass, and waste. Methanol produced from these alternative carbon-containing sources is referred to as bio-methanol. Bio-methanol has the same chemical properties as conventional methanol. The processing steps are almost the same for bio-methanol and fossil methanol production. Bio-methanol only requires an additional step of pretreatment for its' feedstock.²⁴⁰

²³⁷ CIMAC, 2020

²³⁸ CIMAC, 2020

²³⁹ CIMAC, 2020

²⁴⁰ IEA-ETSAP, IRENA, 2013

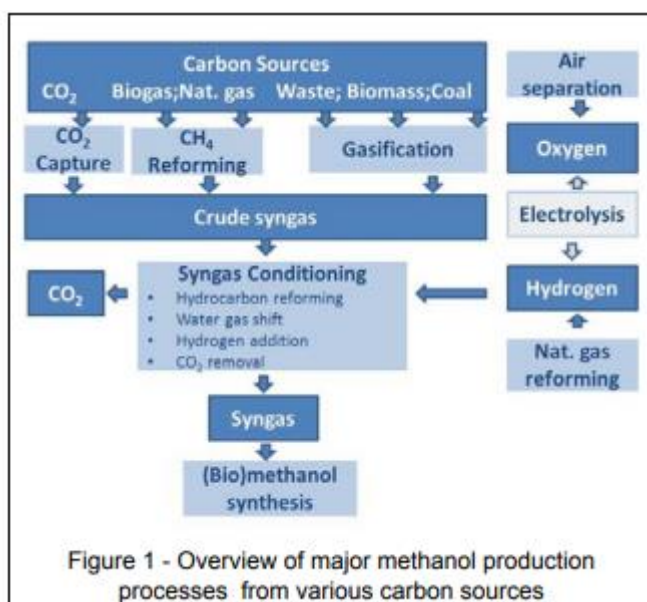


Figure 24. Overview of major methanol production processes from various carbon sources²⁴¹

As illustrated above, when methanol is produced from biogas, it follows the same process steps as natural gas. Biomass and waste share the same process steps with coal for methanol production. The energy efficiency of SMR (natural gas, biogas) is generally higher than for gasification, because gasification (coal, waste, biomass) feedstocks have lower hydrogen/carbon ratios and higher ash and char contents.²⁴²

The SMR route must be modified for biogas if used instead of natural gas, because biogas contains more carbon dioxide than natural gas, thus affecting the composition of crude syngas produced.²⁴³

²⁴¹ IEA-ETSAP, IRENA, 2013

²⁴² IEA-ETSAP, IRENA, 2013

²⁴³ IEA-ETSAP, IRENA, 2013

The process energy for bio-methanol production is sometimes co-produced in the facility from biomass, resulting in lower life cycle GHG emissions of the produced bio-methanol. The source of electricity and heat used in the processing of bio-methanol can be switched from fossils to renewables to lower the emissions from production.²⁴⁴

Producing methanol from waste wood in a free-standing plant is estimated to reduce GHG life cycle emissions by 86 per cent compared to the fossil counterpart.²⁴⁵

²⁴⁴ Jeswani, Chilvers, and Azapagic, 2020

²⁴⁵ European Union, 2018/2001 Directive

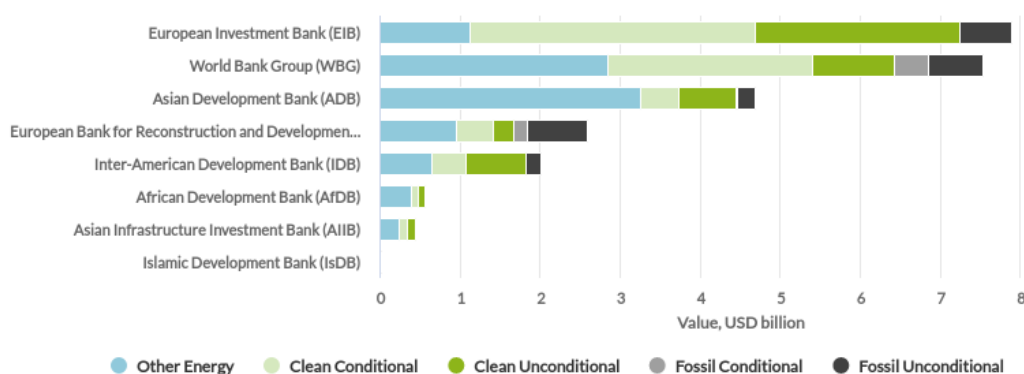
3 GLOBAL CLIMATE RELATED REGULATIONS FOR THE ENERGY SECTOR

Eight Multilateral Development Banks (MDBs) committed 25,72 billion US dollars to energy projects in the early 2020, in the beginning of the pandemic. Fossil fuel energy was supported with around 3,1 billion US dollars, of which 2,25 billion was directed towards oil and gas projects. Finance committed to clean energy amounted to 13,15 billion. A large portion of the finance is directed towards government loans, technical assistance, energy infrastructure, and investments to financial intermediaries, such as commercial banks, other development funds, and private equity firms.²⁴⁶

The climate finance provided by MDBs is provided in varying forms. Loans are one of the most common forms of climate finance. Grants are a form of concessional finance, which is usually not intended to be paid back. Bonds are a type of finance which uses the proceeds of a project to finance other climate projects. Guarantees are designed to attract private investments by de-risking projects. Policy-based financing is provided with the intention of helping public borrowers fulfil national policies, and result-based financing is given out to public entities with accountability requirements attached.²⁴⁷

²⁴⁶ Energy Policy Tracker, 2022

²⁴⁷ AfDB, ADB, AIIB, EBRD, EIB, IDBG, IsDB, NDB, WBG, 2021



Source: energypolicytracker.org, Apr 6 2022

Figure 25. Public money commitments to fossil fuels, clean and other energy in MDBs spending since January 2020, USD billion, as of 4 May 2022²⁴⁸

The European Investment Bank is the biggest MDB source of finance for the energy sector, followed by the World Bank Group and the Asian Development Bank. The Islamic Development Bank is the smallest source of finance within the listed MDBs in the energy sector. The IsDB financed one fossil fuel project in 2020 according to Energy Policy Tracker.²⁴⁹

A commonality the eight biggest Multilateral Development Banks share is the help they provide for client countries to reach Sustainable Development Goals and the Paris Agreement commitments. The MDBs provide increasing amounts of climate finance, mobilize private capital, provide technical assistance, and aid countries to formulate NDCs and achieve them, among other practices which promote the realization of these goals and commitments.^{250,251}

²⁴⁸ Energy Policy Tracker, 2022

²⁴⁹ Energy Policy Tracker, 2022

²⁵⁰ AfDB, ADB, AIIB, EBRD, EIB, IDBG, IsDB, NDB, WBG, 2021

²⁵¹ COP26, 2021

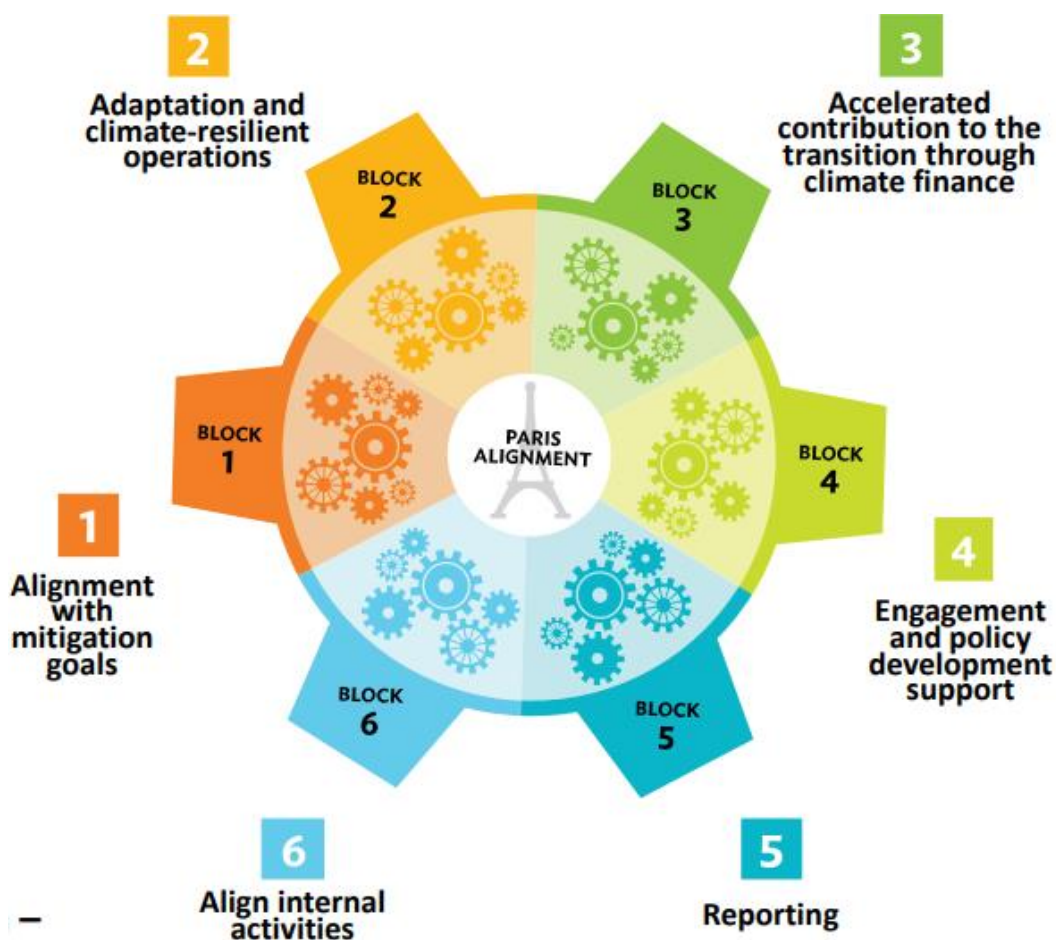


Figure 26. Six building blocks and principles jointly agreed by the MDBs as core areas for aligning with the Paris Agreement²⁵²

Figure 26 illustrates the six building blocks that MDBs jointly agreed on to align their activities with the Paris Agreement.²⁵³

The energy sector financing practices of the eight biggest MDBs are discussed in the upcoming sections, alongside OECD's and E3F's energy sector practices, and

²⁵² MDB Paris Alignment Working Group, 2019

²⁵³ MDB Paris Alignment Working Group, 2019

the EU's recent energy sector regulation developments. The Table 3 below provides an overview of the individual MDBs' financing practices of selected energy sources.

Table 3. Overview of MDB Support for Different Forms of Energy

Bank	Down-stream oil	Down-stream gas	Midstream gas	Coal	Hybrid solutions
AfDB (2012)	Yes	Yes	Yes	Yes	Yes
ADB (2021)	Yes (Conditional)	Yes (Conditional)	Yes (Conditional)	No	Yes
IADB (2018)	Yes	Yes	Yes	No	Yes
IsDB (2018)	Conditional	-	-	-	-
AIIB (draft)	No	Yes	Yes	No	Yes
EBRD (2018)	-	Yes (Conditional)	Yes (Conditional)	No	-
World Bank (2021)	-	Yes (Conditional)	Yes (Conditional)	No	Yes
EIB	No	No	No	No	No

3.1 Export Finance for Future

Governments provide export credits through Export Credit Agencies (ECAs). Export Credit Agencies are companies working on behalf of the government. The purpose of ECAs is to promote national economy by promoting and de-risking the export of goods and services to foreign countries. The role of public institutions has become the most important source of export finance. The ECAs grant export credits in different forms. The different forms include interest rate support, guarantees, insurance, and so on.^{254,255}

There are international agreements and regulations on ECGs (Export Credit Guarantees) to ensure that a country cannot compete with their ECGs and gain competitive leverage through them. European Union and OECD create universal guidelines for member countries to 'level the playing field' amongst them. OECD's Officially Supported Export Credits is the most prevalent agreement on export credits within the organization's member countries. The members of Export Finance for Future are also members of the OECD.²⁵⁶

Export Finance for Future was founded in April 2021 by France, the Netherlands, Denmark, Spain, Germany, United Kingdom, and Sweden in the first Export Finance for Future (E3F) summit. The coalition's objective is to mitigate greenhouse gas emissions by using financial instruments, export finance, and official trade. A Statement of Principles was created to outline these commitments and means of mitigating GHG emissions.^{257,258}

²⁵⁴ OECD, 2021

²⁵⁵ Barone, 2020

²⁵⁶ Finnvera

²⁵⁷ L'Agence France Trésor, 2021

²⁵⁸ L'Agence France Trésor, 2021

The Statement of Principles established that exports of unabated coal, as well as related infrastructures and supply chain activities, will no longer receive official trade or export finance support. The official trade and export finance support is going to be directed to favor sustainable projects. The E3F coalition is harnessed to decrease the prevalence of oil and gas in the energy sector. As stated in the Statement of Principles, the export finance aims to promote innovation, investments in climate resilient technologies and infrastructures, GHG reductions in the energy sector, decarbonization of transport, and transitioning emission-intensive industries.²⁵⁹

Finland, Belgium, and Italy joined the coalition in November 2021 during the second summit of E3F. The summit's conclusions were summarized in a statement. The statement established that new direct public support of global unabated fossil fuel energy will be discontinued within the year of 2022. However, the member countries of E3F will define for themselves the pace and extent of phasing out direct public support for unabated fossil fuels. The coalition members will announce their established procedures in doing so within the year of 2022.^{260,261}

3.2 Organization for Economic Co-operation and Development

Organization for Economic Co-operation and Development (OECD) is an organization that creates standards, initiatives, and programmes through government collaboration. OECD and its key partners combined constitute 80 per cent of global trade and investment. The organization has 38 member countries and 5 'key partner' countries. The member countries apply common standards and policies created by the OECD. The organization harnesses economies, business actions, and

²⁵⁹ L'Agence France Trésor, 2021

²⁶⁰ Government of the Netherlands, 2021

²⁶¹ Gencsu, Sharma, and van der Burg, 2021

policies to make changes in environmental, social, and economic landscapes. Additionally, OECD is an advisor to G20, delivering analytical data and reports to support policymaking. OECD publishes over 500 country surveys and data-analytical reports annually to provide information in support of policymaking. OECD's legal instruments include decisions, recommendations, arrangements, declarations, international agreements, and understandings. International agreements and decisions are legally binding. The other legal instruments are generally not legally binding, but can hold political value, because they are often made with the consensus of member countries.^{262,263,264,265,266}

OECD administers Official Development Assistance (ODA), which is granted to developing economies by OECD member countries' national governments. The objective of ODA is to accelerate the economic growth and promote welfare in developing countries with the aid of developed countries. ODA has been aligned with the goals of the Paris Agreement in each financed activity. Renewable energy and energy efficiency are prioritized in energy sector finance. Coal projects will not receive ODA support anymore, except for CCUS and projects which do not extend the lifetime of a coal-fired power plant.^{267,268}

OECD launched the International Programme for Action on Climate (IPAC) in May 2021, which has a goal of helping countries transition to climate-neutrality and sustainable economies by 2050. OECD contributes to the cause by considering the

²⁶² OECD

²⁶³ OECD, 2019

²⁶⁴ OECD

²⁶⁵ OECD

²⁶⁶ OECD, 2022

²⁶⁷ OECD

²⁶⁸ OECD, 2022

goal in policymaking, harnessing investments and finance, tracking progress, and engaging other parties to reach the common goal.²⁶⁹

The reason why the 2050 climate-neutrality goal is not on the right trajectory from OECD's perspective is insufficient emission fees and taxes, as well as varying degrees of climate ambition reflected by Nationally Determined Contributions. The efforts need to be unified in order to reach the set goals. OECD also thinks that an increasing number of individual countries need to pledge to the net zero emissions by 2050 target.

OECD analyses the progress made towards reaching the Paris Agreement goal of committing 100 billion dollars annually to developing countries' climate finance. The target was initially set to be reached in 2020, but was later postponed to 2025.^{270,271}

OECD has been tracking the goal through four financial components, including officially supported export credits, multilateral and bilateral public climate finance, and the private finance mobilized by the public finance granted. All of the climate finance tracked is initiated by developed countries for the benefit of developing countries.²⁷²

The results from OECD's progress data analytics show that the investments were around 80 billion US dollars in 2019 (See Figure 27). The target being an annual

²⁶⁹ OECD, 2021

²⁷⁰ OECD, 2020

²⁷¹ OECD

²⁷² OECD

100 billion, the finance ended up 20 billion short. OECD predicts that the 100 billion target would be achieved in 2023, two years early of the pledged commitment.^{273,274}

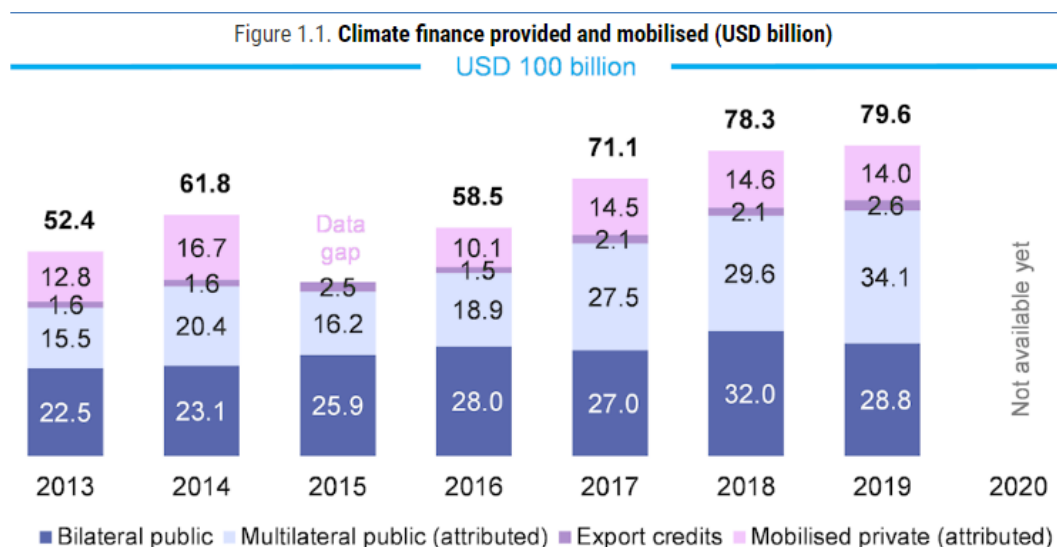


Figure 27. Climate finance provided and mobilized (USD billion)²⁷⁵

As illustrated by Figure 27, the multilateral public climate finance has experienced a continuous growth since 2016. The role of export credits has been on an upward trajectory as well, though its' share is small in comparison to the dominating public finance measures. The share of bilateral public finance and private finance decreased in 2019 from the previous year.²⁷⁶

Multilateral public climate finance includes the contributions of MDBs and climate funds. The finance takes the forms of equity investments, grants, and loans. The multilateral public climate finance mainly constituted of MDB finance, with a con-

²⁷³ OECD

²⁷⁴ OECD

²⁷⁵ OECD

²⁷⁶ OECD

tribution of 30 billion from the total of 34,1 billion. The rest was provided by climate funds. MDBs made a collective announcement in 2019 that they strive to invest 65 billion in climate finance by the year of 2025, estimating that the provided finance would attract an additional 40 billion in private climate finance.^{277,278}

The majority of public climate finance constituted of loans, followed by grants, and with a minimal contribution of equity. Around a third of the total climate finance has been consistently directed to energy sector projects. Asia received most of the financing with a 40 per cent share, followed by Africa with 26 per cent.^{279,280,281}

OECD's 'Recommendation of the Council on Common Approaches for Officially Supported Export Credits and Environmental and Social Due Diligence' is applied by the member countries' Export Credit Agencies (ECAs). The OECD's Common Approaches is not legally binding. However, the common approaches were agreed on by the members, entailing that they are politically integrated.^{282,283}

The purpose of Common Approaches is to promote coherence within the adherents' policies on officially supported export credits. The recommendation encourages the adherents to review projects based on World Bank Performance Standards and the World Bank's EHS guidelines. The Performance Standards' GHG implications are discussed separately in 3.3. World Bank.²⁸⁴

The Common Approaches outlines the environmental, human rights, climate change, and social policies applicable to export credits in OECD member countries.

²⁷⁷ COP26

²⁷⁸ OECD

²⁷⁹ OECD

²⁸⁰ OECD, 2021

²⁸¹ OECD, 2021

²⁸² European Union, 2019

²⁸³ OECD, 2016

²⁸⁴ OECD, 2022

The objective is to level the playing field, by encouraging competition based on attributes such as quality and price, instead of export finance policies. If a development bank is involved in a project, their standards are used in the review of the environmental and social impacts of the project, as well. The project will always have to align with the host country's national laws. The member countries must report how their ECAs implement the Common Approaches to OECD.²⁸⁵

3.3 World Bank

The World Bank is the biggest multilateral source of climate finance for developing countries. The World Bank's mission is to reduce poverty by facilitating inclusive sustainable development and economic growth. The World Bank Group consists of five institutions: IFC, IBRD, IDA, ICSID, and MIGA.^{286,287}

The International Finance Corporation's (IFC's) function is to provide finance as equity and loans, as well as mobilize external capital and private sector investments to developing countries. The Multilateral Investment Guarantee Agency (MIGA) offers political risk insurance and credit enhancement services to investors and lenders. The International Bank for Reconstruction and Development (IBRD) aids middle-income and creditworthy low-income governments. The International Development Association (IDA) issues concessional grants and loans to low-income countries' governments. The International Centre for Settlement of Investment Disputes (ICSID) handles investment disputes.²⁸⁸

²⁸⁵ OECD, 2022

²⁸⁶ World Bank, 2021

²⁸⁷ World Bank, 2021

²⁸⁸ World Bank, 2021

IFC and MIGA provide finance for private sector projects. IDA and IBRD operate mainly in the public sector within government-run projects. IFC and MIGA promote sustainable growth by opening new markets for private sponsors. The success of private projects is affected by the public infrastructure investments. Both public and private finance is needed for the economic growth of middle- and low-income countries.^{289,290}

3.3.1 Performance Standards

The World Bank Performance Standards, formerly called IFC Performance Standards, are now applied by each institution of the Bank, with the exclusion of ICSID. The World Bank Performance Standards on Environmental and Social Sustainability were deployed in 2012. The Performance Standards are widely used in project and development finance to evaluate the perceived social and environmental risks. The standards were used by 70 international banks, 30 Export Credit Agencies of OECD's member countries, and European Development Finance Institutions (EDFIs) in 2012. Many private businesses also use the Performance Standards to evaluate social and environmental risks. The divisions of IFC, MIGA, IDA, and IBRD of the World Bank use Performance Standards for projects they finance and support. When IFC and MIGA finance projects, the Performance Standards are applied to the whole project. When IDA or IBRD finances projects, Performance Standards are solely applied to sub-projects which entail private participation. ESF guidelines are applied to the sub-projects which are conducted by public entities. EHS Guidelines are applied to all projects financed by the Bank.²⁹¹

²⁸⁹ World Bank, 2012

²⁹⁰ World Bank

²⁹¹ World Bank, 2012

World Bank Performance Standard 3 covers resource efficiency and pollution prevention. Greenhouse gases and water consumption are discussed under resource efficiency, and wastes, hazardous materials management, and pesticide use are discussed under pollution prevention.²⁹²

As stated by Performance Standard 3, the project needs to arrange the design and processes of the project to spare raw materials, energy, and water in core-business activities. The project should also adopt GHG emission mitigation measures when they are financially and technically feasible, for the duration of the project implementation and its operation. Energy efficiency should also be improved when technically and economically feasible. If the project is estimated to result in over 25000 tonnes of GHG emissions as carbon dioxide equivalents per year, the direct and indirect emissions of the project need to be reported. The reporting must be done on an annual basis.^{293,294}

3.3.2 Environmental and Social Framework

The World Bank developed a new Environmental and Social Framework (ESF), which manages project risks and impacts on environment and society. ESF was applied from October 2018 onwards to new projects taken on by the Bank. The framework replaced the previously used Safeguard Policies. The Safeguard Policies are still adopted by projects financed before 2018. After a transition period of seven years, the Safeguard Policies are taken out of practice. ESF is used by IBRD

²⁹² International Finance Corporation, 2012

²⁹³ International Finance Corporation, 2012

²⁹⁴ International Finance Corporation, 2012

and IDA, which fund public projects. Private entities need to comply with Performance Standards instead of ESF. The World Bank's EHS guidelines are referred to in all projects.^{295,296}

The ESF consists of ten Environmental and Social Standards (ESSs). The ESF guidelines' ESS3 covers Resource Efficiency and Pollution Prevention and Management. The objectives of the standard are to conserve energy, water, and other resources, as well as to avoid and minimize GHG emissions, waste, and environmental and health impacts.²⁹⁷

The pollutant release is managed by EHS guidelines or national laws of the host country, according to the strictest one of the two. Adopting energy efficiency measures and renewable energy are proposed as ways to reduce the release of pollutants and GHGs. The quantification of GHG emissions is mandated when it is economically and technically feasible. The Bank also provides technical assistance to fulfill the task if the borrower needs it.²⁹⁸

3.3.3 World Bank Climate Change Action Plan 2021-2025

The World Bank formulated a new Climate Change Action Plan, which is applicable to the Bank's lending between the years of 2021 and 2025. The Action Plan outlines the World Bank's climate change mitigation and adaptation measures for the established period. According to the Action Plan, the World Bank will align all of its' activities within IDA and IBRD to be consistent with the Paris Agreement, by the year of 2025. Additionally, the entire World Bank Group will dedicate 35 per

²⁹⁵ World Bank

²⁹⁶ IDA, 2021

²⁹⁷ World Bank, 2017

²⁹⁸ World Bank, 2017

cent of total lending to climate finance during the period. Half of IDA's and IBRD's climate finance will be directed towards adaptation.²⁹⁹

The Bank invests in energy projects which provide energy access to lacking regions. Low-carbon energy sources are prioritized, while keeping in mind the resiliency to climate change induced extreme events. Attention is paid to energy efficiency as well. Coal power plant decommissioning within high-emitting, emerging economies is an important driver of global GHG mitigation. The commercialization of green technologies is recognized as crucial for GHG emission abatement.³⁰⁰

The World Bank aids client countries in the formulation of carbon pricing tools to accelerate decarbonization through financial instruments. The Bank will always consider a country's NDCs when evaluating projects, since they are the most effective at portraying the national climate change mitigation and adaptation aspirations and preferred terms of reaching them.³⁰¹

Coal mining and coal-based electricity production are not financed by the Bank. The Bank helps client countries with repurposing old coal mines and coal-fired power plants. Peat extraction and electricity production are not funded either. Oil pipelines have not been funded by the Bank since 2014, and the existing practice was made official in 2019, when upstream oil and gas project support was discontinued.³⁰²

²⁹⁹ World Bank, 2021

³⁰⁰ World Bank, 2021

³⁰¹ World Bank, 2021

³⁰² World Bank, 2021

Downstream natural gas projects may be funded if lower carbon alternatives are deemed unfeasible, or if the objective is to stabilize the grid or replace, for example, coal usage. Gas infrastructure is financed when such projects align with country's NDCs, the projects do not lead to carbon lock-in, and so on.³⁰³

The World Bank's mini-grid and off-grid solution investments are the highest out of all the MDBs. The Bank is increasing their involvement in offshore wind, green hydrogen, battery storage, electrification, and CCUS project finance. Energy efficiency is financed by the Bank, as it is often effective at delivering GHG reductions with the lowest price attached.³⁰⁴

3.4 European Union Green Deal and Related Processes

3.4.1 European Green Deal

The European Green Deal sets a legally binding target for EU members to become climate-neutral by 2050, and an intermediate goal for 2030 to reduce GHG emissions by at least 55 per cent compared to the 90's level.³⁰⁵

The target of achieving climate neutrality is synonymous with net zero emissions, and essentially entails emitting the same amount of GHG emissions, than what is taken out from the atmosphere. The key elements driving the transition to climate neutrality are cutting emissions, green technology investments, and protection of environment.^{306,307}

³⁰³ World Bank, 2021

³⁰⁴ World Bank, 2021

³⁰⁵ European Commission

³⁰⁶ European Commission

³⁰⁷ European Union, 2021

The European Green Deal is a package of climate-oriented measures. The measures are deployed to support the pursuit of the legally binding target by accelerating the mitigation of GHG emissions and increasing atmospheric carbon removals within EU. The European Green Deal includes climate action initiatives, such as the European Climate Law, the European Climate Pact, 2030 Climate Target Plan, and the EU Strategy on Climate Adaptation. Energy System Integration Strategy and the Hydrogen Strategy, among other strategies, have been revised to align with the objectives of the European Green Deal. Some of the proposed revisions are discussed in this chapter.³⁰⁸

The EU published the “Fit for 55” package in July 2021. The proposed package aims to bring EU legislation in line with the 2030 goal. Revisions were proposed to the Energy Efficiency Directive (EED), the Renewable Energy Directive (RED), and other EU documents.^{309,310}

The EU promotes and encourages ambitious climate policies in the international context, for example through channels such as G7, G20, the World Trade Organization, and the United Nations. The EU also puts effort forward to establish international carbon markets through collaboration with global partners. The EU leverages its’ economic status to guide the international standards to correspond with the Union’s ambition level in climate change mitigation.³¹¹

³⁰⁸ European Commission

³⁰⁹ European Commission, 2021

³¹⁰ European Commission, 2021

³¹¹ European Commission, 2019

3.4.2 Energy Efficiency Directive

The proposed revision of the Energy Efficiency Directive (EED) puts emphasis on the overarching principle of the EU's energy policy 'energy efficiency first'. Investment decisions and policy will be guided by this principle.³¹²

The current Energy Efficiency Directive (EED) has a non-binding target of improving energy efficiency by 2030 with 32,5 per cent. The former target of 32,5 per cent set out in the 2018 Directive was for both, final and primary energy consumption. The suggested revision of EED would increase the ambition to 36 per cent for final energy consumption, and 39 per cent for primary energy. The goal would be made legally binding.^{313,314,315}

The new goal is achieved by improving the annual energy saving rate in energy end-use by 1,5 per cent each year between 2024 and 2030. The current energy saving rate is 0,8 per cent, as set out in the 2018 Energy Efficiency Directive. The revised directive would create momentum to achieve these goals by focusing on energy sub-sectors which have high energy saving potentials, such as buildings, industry, heating and cooling, and energy services. The role of the public sector is important within the transition, and it is further emphasized in the revised directive. Thus, 1,7 per cent of annual energy savings are required of each EU member's public sectors. In honour of that, 3 per cent of the floor area in public buildings is required to be renovated annually.^{316,317,318,319}

³¹² European Commission

³¹³ European Commission, 2021

³¹⁴ European Commission

³¹⁵ European Commission, 2021

³¹⁶ European Commission, 2021

³¹⁷ European Commission

³¹⁸ European Commission, 2021

³¹⁹ European Commission, 2021

Buildings show great energy efficiency improvement potential. Around 75 per cent of buildings have poor energy efficiency. Heating and cooling covers 80 per cent of energy use in buildings. The revised EED introduces an emission limit of 270 gCO₂/kWh for high-efficiency energy co-generation. Additionally, co-generation of natural gas needs to achieve 10 per cent primary energy savings compared to separate production of heat and electricity.^{320,321,322,323}

3.4.3 Renewable Energy Directive

The Renewable Energy Directive (RED) is under revision due to the climate-neutrality objectives of the European Green Deal. The proposed revision would entail doubling the share of renewables in the energy mix (from 19,7 to 40 per cent) by 2030. The target is 32 per cent in the currently used 2018 Renewable Energy Directive.³²⁴

The revision of the directive puts emphasis on adopting renewables where their presence is currently lacking. The sectors include buildings, industry, and transport. The proposal promotes renewable hydrogen for applications which are hard to decarbonize through electrification.³²⁵

The revised RED promotes heating and cooling from renewable energy sources, including solar energy, geothermal energy, ambient energy, biogas, biomass, bi-liquids and waste heat and cold, in combination with thermal energy storage.³²⁶

³²⁰ EU Technical Expert Group on Sustainable Finance, 2020

³²¹ European Commission, 2022

³²² European Commission, 2021

³²³ European Commission, 2021

³²⁴ European Commission, 2021

³²⁵ European Commission, 2021

³²⁶ European Commission, 2021

The decarbonization of heating and cooling is addressed with legally binding targets in the proposed revision. Renewable energy and waste heat utilization are increased annually by 1,1 per cent in heating and cooling, 2,1 per cent in district heating and cooling, and 1,1 per cent in industry energy use. Half of the energy used in buildings would be accommodated with renewable energy in 2030.³²⁷

The revised RED sets a target of reducing the emission intensity of transport fuels by 13 per cent by 2030. The share of advanced biofuels is increased to 2,2 per cent, and the share of renewable fuels from non-biological origin (RFNBO) is increased to 2,6 per cent. Electrolyzer capacity is increased to 40GW, and half of industry's energy and non-energy hydrogen consumption needs to be met with renewable hydrogen.³²⁸

The proposed RED would make an important change in the definition of RFNBO. In the current RED, RFNBO can only be accounted towards the EU's GHG emission mitigation targets in the transport sector. The revision of RED would expand RFNBO to contribute to the Union's emission mitigation targets in the energy and power sector as well. The revision will not do the same extension for recycled carbon fuels. The contribution of recycled carbon fuels is accounted for in transport sector GHG mitigation efforts only, just like in the current RED. Both RFNBO and recycled carbon fuels must reduce GHG emissions by 70 per cent compared to fossil fuel in order to be aligned with RED and contribute to EU's targets in their respective sectors.³²⁹

³²⁷ European Commission, 2021

³²⁸ European Commission, 2021

³²⁹ European Commission, 2021

The support for electricity production from biomass is going to be ended in 2026. All biomass-based energy production must comply with the EU's GHG saving thresholds.³³⁰

3.4.4 Industrial Emissions Directive

A revision has been proposed for the Industrial Emissions Directive (IED), which regulates the pollutant emissions of industrial applications. The directive is being revised due to EU's target of a zero-pollution industry by 2050. The IED regulates the emissions based on emission limits set out in the Best Available Techniques (BAT). The BAT is used for permitting. The revision of IED entails revising the Best Available Techniques as well. Around 50 000 installations comply with the directive within EU, of which 30 thousand are large industrial plants. IED and BAT cover a plethora of emissions and pollution to air, water, and soil.^{331,332,333,334,335}

The revised IED entails tightened permitting, flexible permits for installations applying emerging technologies, increased circular economy investments, and giving increased attention to methane emissions and energy efficiency. The extraction of industrial minerals and metals, and production of batteries will be added as regulated activities under IED.^{336,337}

IED regulates GHG emissions which are not covered by ETS, such as methane and fluorinated gases. The revised IED will increasingly contribute to decarbonization by introducing energy efficiency requirements to minimize energy consumption.

³³⁰ European Commission, 2021

³³¹ European Commission, 2021

³³² European Commission, 2022

³³³ European Commission, 2022

³³⁴ European Commission, 2022

³³⁵ European Commission, 2022

³³⁶ European Commission, 2022

³³⁷ European Commission, 2022

The installations regulated by IED need to formulate a plan on how they intend on becoming aligned with sustainable, clean, and climate-neutral economy by 2050. New and existing lean burn gas engines cannot emit more than 215 mg/Nm³ of methane in the revised IED.³³⁸

3.4.5 EU Taxonomy for Sustainable Activities

The EU Taxonomy aids in the pursuit of the European Green Deal's goals by directing investments to sustainable projects and activities. The EU Taxonomy is a classification system for sustainable economic activities. The Taxonomy was established to identify and define these activities and give consensus to what is considered sustainable. The Taxonomy was established before the European Green Deal, but it is an important tool to reach the GHG reduction goals, nonetheless. Since public sector's efforts are not enough to reach climate-neutrality without the private sector's contribution, the Taxonomy will give security to investors in climate-friendly activities, prevent greenwashing, and direct investments where they are most needed. The six Taxonomy objectives include climate change mitigation, adaptation, transition to circular economy, sustainable use of water resources, protecting ecosystems, and pollution prevention and control.^{339,340}

Financial market participants which offer financial services, as well as large corporate companies, need to disclose their activities' alignment with EU Taxonomy. The disclosures inform the amount of Taxonomy aligned activities as a percentage of turnover or expenditures (capex, opex), whichever is deemed appropriate for reporting. The activity needs to substantially contribute to one of the six objectives

³³⁸ European Commission, 2022

³³⁹ European Commission

³⁴⁰ European Commission, 2022

of the Taxonomy, and ‘do no significant harm’ on the other objectives. The Commission estimates that the current corporate alignment with the Taxonomy is low. Only 1-5 per cent of activities and investment portfolios are estimated to be aligned with the Taxonomy. An increase is expected with the implementation of the European Green Deal. The Taxonomy helps attract investments to activities which are aligned, or in the pursuit of becoming aligned with the Taxonomy.^{341,342}

The Taxonomy will possibly be extended to cover environmentally harmful and neutral activities, in addition to the environmentally sustainable activities. The update would entail dividing turnover or expenditures (capex, opex) to three categories. The categories include ‘substantial contribution’, ‘significant harm’, and a neutral category. The turnover or expenditure would thus be divided into percentages of these three categories, giving a more well-rounded understanding of the environmental implications of the company’s portfolio. Multiple energy generating sources are considered sustainable in the first Taxonomy Delegated Act if they emit less than 100 CO₂e/kWh.^{343,344}

A Complementary Climate Delegated Act was established under the Taxonomy to outline the conditions for nuclear and gas projects to be considered sustainable. Categorizing these activities as sustainable will facilitate a transitional shift from oil and coal. The gas activities included in the Taxonomy are high-efficiency heat, electricity, and co-generation energy production. However, these fossil gas activities need to comply with a direct GHG emission limit of 270 g CO₂e/kWh or alternatively an annual GHG emissions average limit of 550kg CO₂e/kW over 20 years,

³⁴¹ European Commission

³⁴² EU Technical Expert Group on Sustainable Finance, 2020

³⁴³ EU Technical Expert Group on Sustainable Finance, 2020

³⁴⁴ EU Technical Expert Group on Sustainable Finance, 2020

replace existing coal or oil plants when replacement is not feasibly done with renewables, and switch to low-carbon or renewable gases by 2035. Additionally, the transition to low carbon gases is done gradually. Thirty per cent of the fuel used needs to be low carbon in 2026, and 55 per cent in 2030. The plant needs to reduce GHG emissions by 55 per cent over its' lifetime.^{345,346,347,348}

Nuclear activities are required to ensure safety and proper waste management practises in order to be covered by the Taxonomy. Nuclear energy is supported because it does not interfere with the development of variable renewable energy, and it provides a low-carbon baseload for the energy sector. The Delegated Act was formally adopted in March 2022.^{349,350,351,352}

3.5 Inter-American Development Bank

The Inter-American Development Bank (IADB) is on a mission to increase the availability, quality, and efficiency of energy within its' operation region, Latin America and the Caribbean (LAC). Cross-border integration, as well as diversifying the energy mix are some of the objectives of the Bank. The energy security of LAC is ensured by investing in energy infrastructure and cross-border energy integration, for more reliable energy services. The main documents outlining the Bank's operations in the energy sector are the Energy Sector Framework from 2018, and the Environmental and Social Policy Framework from 2020.^{353,354}

³⁴⁵ European Commission, 2022

³⁴⁶ European Commission

³⁴⁷ European Commission, 2022

³⁴⁸ European Commission, 2022

³⁴⁹ European Commission, 2022

³⁵⁰ European Commission

³⁵¹ European Commission, 2022

³⁵² European Commission, 2022

³⁵³ IADB, 2022

³⁵⁴ IADB, 2018

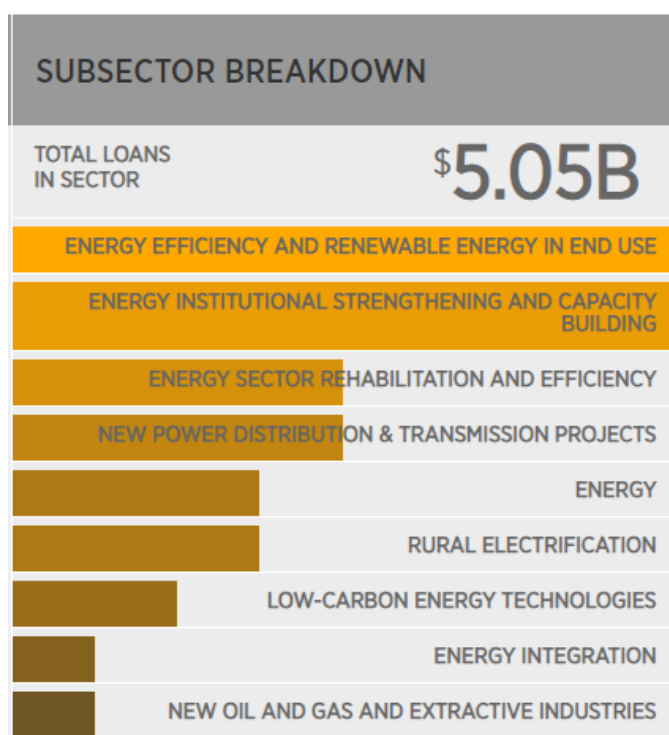


Figure 28. IADB Subsector Breakdown, Total Loans in Energy Sector³⁵⁵

The Latin America and the Caribbean (LAC) region is getting close to achieving the SDG7 of universal access to electricity, with only 3 per cent of the total population still lacking energy services. The advancements are largely due to shifting the preferred method of providing access to power from grid extension to decentralized energy systems, because most of the population still lacking energy access is located in rural and remote areas. Grid extension can be a costly way of accommodating the remote population with energy. The new solution is to supply these regions with off-grid systems of renewable energy and diesel back-ups.³⁵⁶

The Bank tries to minimize electricity losses by addressing technical losses which occur due to unsatisfactory maintenance, poor design of transmission lines, and

³⁵⁵ IADB, 2022

³⁵⁶ IADB, 2018

overloaded transformers. Smart grids are also supported by the Bank to improve the function of the grid.³⁵⁷

According to the Bank, the energy security of LAC is improved by reducing losses, developing natural gas systems, increasing regional energy integration, and investing in energy infrastructure. The Bank suggests improving natural gas distribution by constructing gas pipelines and LNG terminals.³⁵⁸

The Bank supports projects that increase access to high-quality energy services. The projects include grid extension and decentralized systems, energy efficiency and renewable energy adoption, as well as infrastructure investments to reduce electricity losses.³⁵⁹

Mobilization strategies of the Bank will combine institutional, private, and donor funding in the form of private-public partnerships, blended finance, bonds, and guarantees.³⁶⁰

The Bank's investments are mainly directed towards renewable energy projects, natural gas projects, infrastructure for transport and distribution, storage, energy efficiency, and the electrification of remote locations.³⁶¹

The Bank does not support nuclear projects. Fossil fuel is supported when it is economically sensible, for example, to rehabilitate existing power plants, to switch the fuel from coal or oil to natural gas, or to extend the energy supply to lacking regions. The Bank supports fossil fuel energy efficiency improvement projects.³⁶²

³⁵⁷ IADB, 2018

³⁵⁸ IADB, 2018

³⁵⁹ IADB, 2018

³⁶⁰ IADB, 2018

³⁶¹ IADB, 2018

³⁶² IADB, 2018

The Bank does not generally support coal related activities or oil and gas exploration. Gas infrastructure is financed if it provides energy access to low-income population, is consistent with GHG mitigation measures, and supports national climate change goals.³⁶³

The Bank has developed Environmental and Social Performance Standards (ESPSs), which outline the environmental and social risk mitigation measures that the borrower must comply with. The ESPS 3 covers resource efficiency and pollution prevention. The ESPS 3 is identical to the World Bank Performance Standard on resource efficiency and pollution prevention.³⁶⁴

The borrower is encouraged to consider adopting GHG mitigation measures into project design and operation when it is technically and economically feasible. The borrower should refer to EHS guidelines' section on resource efficiency and pollution prevention, or other internationally recognized documents to apply sufficient environmental and social risk management.³⁶⁵

3.6 Asian Development Bank

The Asian Development Bank (ADB) approved their new energy policy in October 2021. The objective of the policy is to gain universal access to affordable and reliable energy, and aid Asia and the Pacific in their pursuit of transitioning to a less GHG intensive energy sector.³⁶⁶

³⁶³ IADB, 2020

³⁶⁴ IADB, 2021

³⁶⁵ IADB, 2021

³⁶⁶ ADB, 2021

The ADB accelerates decarbonization by reducing the GHG intensity of electricity production, while simultaneously increasing the share of electricity in the total energy consumption. Energy efficiency improvements are supported over adding new energy production capacity due to the economic implications of EE.^{367,368}

The projects which are not supported by the ADB include upstream and midstream oil activities, coal projects (except for decommissioning), nuclear, and natural gas exploration.³⁶⁹

The most rural and remote areas are supplied with energy through mini-grids and off-grid energy solutions. Battery storage solutions will further the adoption of these systems in the future. Even though upstream and downstream oil activities are not supported by the Bank, selected downstream oil projects are given consideration, such as hybrid energy systems. Additionally, oil projects may be financed if there are plans in place to reduce oil dependence in the future.^{370,371}

The Bank finances transmission and distribution, for example by enhancing the reliability of the networks, connecting generation capacity to the grid, expanding to underserved regions, and engaging in projects which reduce technical losses and power outages.³⁷²

Interconnectivity is promoted with the objective of improving energy security and system stability, as well as reducing generation costs and system losses. In addition to electricity interconnectivity, gas pipeline cooperation is promoted as well.³⁷³

³⁶⁷ ADB, 2021

³⁶⁸ ADB, 2021

³⁶⁹ ADB, 2021

³⁷⁰ ADB, 2021

³⁷¹ ADB, 2021

³⁷² ADB, 2021

³⁷³ ADB, 2021

Coal mining, storage, processing, transportation, and new coal-fired plants are not supported by the Bank. The ADB does not invest in upgrades or rehabilitations of existing coal power plants that would extend the operation of the coal-fired heating or power plant. However, decommissioning and repurposing these power plants is supported.³⁷⁴

The Bank estimates that natural gas consumption of developing member countries will increase up until 2030. The Bank recognizes that natural gas reduces carbon dioxide emissions when it is used instead of oil or coal. The ADB also thinks that natural gas might support the penetration of renewables when used as balancing power. However, the Bank is wary of the impact of natural gas in the long-term landscape of climate change. The Bank supports natural gas projects with caution.^{375,376}

The Bank does not finance natural gas exploration. Midstream and downstream activities gain limited support. Natural gas projects are generally considered for financing when they provide power system flexibility, deliver access to energy for the underserved population, or replaces oil or coal. The projects must be energy efficient and utilize best available technologies. Natural gas infrastructure may be funded by the Bank in the form of pipelines, storage facilities, and LNG terminals.³⁷⁷

Additionally, natural gas projects are not financed if lower carbon alternatives could deliver the same service for the same price, or if the project is subject to becoming stranded assets in the future.³⁷⁸

³⁷⁴ ADB, 2021

³⁷⁵ ADB, 2021

³⁷⁶ ADB, 2021

³⁷⁷ ADB, 2021

³⁷⁸ ADB, 2021

The ADB finances CCUS projects. Enhanced oil recovery related CCUS is not supported by the Bank.^{379,380}

The ADB's Safeguard Policy Statement (SPS) consists of the environment and social safeguards of the Bank's activities. The purpose of the SPS is to manage the environmental and social impacts of a project. The SPS consists of three safeguards: environmental safeguards, involuntary resettlement safeguards, and indigenous people's safeguards. The Bank does not finance projects which do not comply with the safeguards or the host country's national laws. The World Bank's EHS guidelines can also be used for additional information, where the sourcebook of ADB does not provide exhaustive information.³⁸¹

3.7 African Development Bank

The objective of the African Development Bank (AfDB) is to mitigate poverty in its' regional member countries (RMCs) by evoking social progress and sustainable economic growth. The AfDB directs investments and mobilizes additional funds to accomplish the objective. Just like all MDBs, the AfDB is committed to the Sustainable Development Goals. The main document referenced is the AfDB's energy strategy from 2012.³⁸²

The importance of investing in infrastructure for economic growth is recognized as an area of improvement in Africa. These investments are estimated to increase the African GDP by two per cent. The African Development Bank has invested in transport, water, and energy to achieve this goal.³⁸³

³⁷⁹ ADB, 2021

³⁸⁰ ADB, 2021

³⁸¹ ADB, 2012

³⁸² AfDB

³⁸³ AfDB

The completed projects from the year of 2020 effectively improved energy availability, and reduced GHG emissions within the region. Electricity was provided to 260 000 people without previous access, power capacity was increased by 202 MW (half being renewable), and carbon dioxide emissions were reduced by 1,6 million tonnes.³⁸⁴

The New Deal on Energy for Africa was launched in 2018 to achieve energy access for all by 2025 through public-private partnerships. Additionally, the AfDB mobilized almost 110 million US dollars of climate finance from external climate funds, including the Green Climate Fund, the African Climate Change Fund, the Climate Investment Funds, and the Global Environment Facility.^{385,386}

The aim of AfDB's energy policy is to extend the energy access for the whole African population, and to do it in an environmentally, economically, and socially sustainable way. The AfDB does not prohibit the utilization of fossil fuels to fulfill the goal. While fossil fuel power generation is supported by the AfDB, clean and efficient energy is preferred when it is economically feasible.³⁸⁷

As of 2013, the AfDB supports the use of coal, arguing that Africa has large coal reserves that can be utilized to improve access to inexpensive energy within the continent.³⁸⁸ The AfDB bases its' coal project financing decisions on a set of criteria: increasing energy accessibility of the low-income population, improving regional energy security, and reducing GHG emissions. Coal mine exploration is not supported by the Bank.³⁸⁹

³⁸⁴ AfDB, 2021

³⁸⁵ AfDB, 2021

³⁸⁶ AfDB, 2018

³⁸⁷ AfDB, 2012

³⁸⁸ AfDB, 2012

³⁸⁹ AfDB

The AfDB's recommended GHG mitigation measures for thermal power plants include using less carbon intensive fossil fuels, such as natural gas, using carbon neutral fuels like biomass, combined heat and power plants, energy efficient thermal power plants, monitoring and managing combustion efficiency, and improving efficiency by reducing transmission losses.^{390,391}

The Bank supports African oil and gas processing, distribution, export, and production. The Bank does not support oil and gas exploration, nor nuclear energy.^{392,393}

Home Systems (SHS) and Green Mini Grids are utilized to provide energy access to underserved regions. In addition to these decentralized energy solutions, the Bank invests in electricity infrastructure in the form of grid extensions and power generation capacity.³⁹⁴

Biofuel production is supported by the AfDB when the production does not impair food security or biodiversity, contributes to rural development, reduces carbon dioxide emissions on a life cycle basis, and does not lead to poverty.³⁹⁵

The energy policy of the Bank also highlights the importance of energy efficiency in furthering the development of the continents' energy sector beyond adding new generation capacity. In fact, the Bank prefers energy efficiency improvement projects over new energy generation capacity projects due to economic implications and the duration of commissioning periods.³⁹⁶

³⁹⁰ AfDB, 2015

³⁹¹ Tralac, 2015

³⁹² AfDB, 2012

³⁹³ AfDB

³⁹⁴ AfDB

³⁹⁵ AfDB, 2012

³⁹⁶ AfDB

The Bank supports regional large-scale energy projects of, for example, fossil fuels, solar, hydropower, and geothermal, as well as regional and cross-border oil and gas pipelines.³⁹⁷

The AfDB has five operational safeguards for addressing environmental and social risks that the clients are required to meet during the project's life cycle. The operational safeguards include environmental and social assessment, involuntary resettlement land acquisition, population displacement and compensation, biodiversity and ecosystem services, pollution prevention and control, hazardous materials and resource efficiency, and labor conditions, health, and safety. Both private and public clients need to comply with the operational safeguards. The ISS system was developed in 2013 to coincide with the AfDB's new ten-year strategy and other multilateral development institutions' policies.³⁹⁸

Operational Safeguard 4 regarding pollution prevention and control, hazardous materials and resource efficiency is based on the EHS guidelines and applies to private and public sectors. The World Bank Group's Environmental, Health and Safety (EHS) Guidelines are applied to greenhouse gas management and accounting in the AfDB.^{399,400}

3.8 Islamic Development Bank

The Islamic Development Bank (IsDB) is committed to help countries reach the SDG7 goal of providing energy access for all, while honouring the Paris Agreement target of limiting global warming to 1,5 degrees. The Bank will select projects

³⁹⁷ AfDB, 2012

³⁹⁸ AfDB, 2013

³⁹⁹ AfDB, 2015

⁴⁰⁰ AfDB, 2013

based on each member country's individual needs. The selection will always comply with sustainable development criteria, which are applied across all the MDBs.^{401,402}

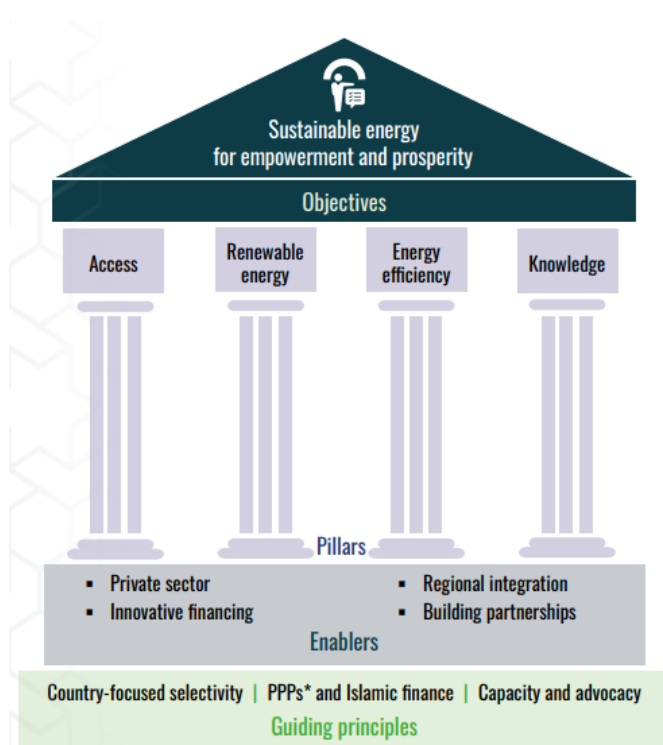


Figure 29. Framework for the Energy Sector Policy⁴⁰³

The above Figure 29 illustrates the main pillars and objectives of IsDB's energy policy. The bank will strengthen the energy sector by partnerships, by regional integration, by attracting private capital, and by deploying innovative finance mechanisms. The Bank promotes clean energy and energy efficiency whenever possible.⁴⁰⁴

⁴⁰¹ IsDB

⁴⁰² IsDB, 2018

⁴⁰³ IsDB, 2018

⁴⁰⁴ IsDB, 2018

The Bank strives to fulfil the SDG7 goal of contemporary, affordable, and reliable energy for all by distributed generation, decentralized energy systems, transitioning to modern energy services, extending the energy infrastructure, and consolidating the existing infrastructure.⁴⁰⁵

The Bank promotes solar power, hydropower, and energy efficiency projects. Oil and gas projects are evaluated based on sustainability, safety, and efficiency. The Bank does not support nuclear energy.⁴⁰⁶

Solar PV is favoured as a solution to supply remote populations with energy via mini-grid and off-grid energy systems. According to the IsDB, the underlying motivation for increasing renewable energy in some of the Bank's member countries is to liberate more oil and gas for export.⁴⁰⁷

The IsDB does not restrict the financing of fossil fuel projects in their energy policy. However, the Bank helps member countries decarbonize the energy sector, and supports their NDC implementation efforts. The IsDB has also excluded coal infrastructure energy efficiency projects, upstream fossil fuel extraction, production, distribution, and transportation of coal, oil, and natural gas from 'green finance'. The Bank, however, does not exclude 'non-green' investments from their financing practices.^{408,409}

Safeguard policies are a way of managing social and environmental risks of the projects a development bank finances. The IsDB just recently published their own safeguard policies, in 2020. The IsDB used to solely comply with target country's regulation, or other MDBs safeguard policies when co-financing projects. The Bank

⁴⁰⁵ IsDB, 2018

⁴⁰⁶ IsDB, 2018

⁴⁰⁷ IsDB, 2018

⁴⁰⁸ E3G, 2020

⁴⁰⁹ E3G, 2020

recognises that the lack of social and environmental safeguard policies has limited its' partnerships with other MDBs, bilateral institutions, and multilateral funds. The Bank has now created its' first environmental and social safeguard policies (ESSP) which are aligned with global best practices. The Bank thinks that the new ESSP will benefit the member countries due to increased access to global resources. The Bank will now consider the sustainability aspects in the financing decisions of projects.⁴¹⁰

Environmental and social impact assessment is required for projects that have significant social and environmental risks. The project is then recommended to manage the risks by avoidance, mitigation, or compensation. Recommendations for risk mitigation are provided by the Bank. The IsDB monitors that the client manages the risks of the project and takes measures compliant with the Bank's guidance. The Bank states that the new ESSP was formulated by combining some of the aspects of already existing safeguard policies, adopted by other institutions. The policy was enforced in 2021.⁴¹¹

3.9 Asian Infrastructure Investment Bank

3.9.1 Current Energy Strategy

The Asian Infrastructure Investment Bank (AIIB) developed an 'Energy for Asia Strategy' to guide activities in the energy sector in 2017. The strategy was amended in 2018. The Energy Strategy is currently being revised. The current Energy Strategy is discussed in this chapter, and the revision in the next one.^{412,413}

⁴¹⁰ IsDB, 2020

⁴¹¹ IsDB, 2020

⁴¹² AIIB, 2018

⁴¹³ AIIB, 2017

The objective of the strategy is to help member countries increase access to safe, reliable, and clean energy while honouring the Paris Agreement's target of limiting global warming to 1,5 degrees. The Strategy recognizes the importance of universal energy access to end poverty and promote economic growth.^{414,415}

The six principles of the AIIB's energy strategy are promoting energy access, realizing energy efficiency potential, decarbonizing the energy supply, managing local and regional pollution, mobilizing private capital, and promoting regional co-operation and connectivity.⁴¹⁶

Asia has massive reserves of oil, gas, and coal, as well as good exploitation potentials of hydropower, solar, and geothermal. Thus, the Bank takes advantage of these potentials by not excluding oil and gas extraction investments. However, the Bank decarbonizes the energy sector by reducing investments in oil and coal. Natural gas investments will be slightly reduced as well. Renewable energy, low-carbon energy, and energy efficiency investments are increased. The Bank supports centralized and decentralized renewable energy projects. Nuclear power projects are not financed by the AIIB.⁴¹⁷

The Bank finances some fossil fuel energy production projects. Gas-fired power generation is considered to selected countries. Oil and coal projects are supported in three possible scenarios: When improving the efficiency of existing capacity, the capacity is essential for system reliability, or if alternatives are not feasible. Each country's NDCs and individual conditions are evaluated when considering these projects.⁴¹⁸

⁴¹⁴ AIIB, 2018

⁴¹⁵ AIIB, 2017

⁴¹⁶ AIIB, 2018

⁴¹⁷ AIIB, 2018

⁴¹⁸ AIIB, 2018

Upstream and midstream activities of oil and gas are supported by the Bank if they improve energy security or promote regional integration. The development and rehabilitation of natural gas distribution is supported by the AIIB, including methane leakage projects. The Bank views gas infrastructure as important for the transition to low carbon future.⁴¹⁹

The Bank finances energy efficiency projects that improve the efficiency of existing electricity generation capacity, reduce fuel consumption, improve energy efficiency through predictive maintenance methods, as well as reduction programs and final use efficiency initiatives. The Bank tries to increase the amount of energy efficiency projects by co-operating with other MDBs and bilateral institutions.⁴²⁰

The Bank supports transmission and distribution projects that aid the adoption of renewable energy, increase resiliency to natural disasters, reduce technical losses, improve reliability of supply, and increase system efficiency with smart grids and digital solutions. Transmission and distribution projects are generally considered to carry low environmental and social risks. Despite this, the social and environmental risks of the transmission and distribution projects are screened.⁴²¹

3.9.2 Drafted Energy Strategy

The Bank is currently in the midst of updating its' Energy Sector Strategy. The drafted strategy announces that the Bank dedicates half of all finance to climate finance by 2025 to honor the Paris Agreement. The new strategy focuses on enabling infrastructure for low carbon electricity and fuels, as well as fuel shifts from coal and oil. The draft would also include the notion that the Bank supports pro-

⁴¹⁹ AIIB, 2018

⁴²⁰ AIIB, 2018

⁴²¹ AIIB, 2018

jects of electricity storage, offshore wind, hybrid renewable energy plants, and hydrogen production. Coal projects are excluded from the Bank's scope of finance. The Bank would, however, finance coal power plant decommissioning and fuel shifts to lower carbon alternatives. Oil projects would not be supported either, except in the context of hybrid energy production for off-grid energy systems. The new stance on natural gas would entail a more accepting outlook due to its' essential role in hard-to-abate sectors during the energy transition. Natural gas is favored also because many member countries have domestic reserves of natural gas, which improve the energy security of said countries. Natural gas is appealing as an enabler of increased intermittent renewable energy generation.⁴²²

3.9.3 Environmental and Social Framework

The AIIB screens all financed projects to ensure that they comply with the Bank's Environmental and Social Framework (ESF).⁴²³ The renewed 2021 Environmental and Social Framework (ESF) is applied to new projects from first of October 2021.⁴²⁴

The Bank requires the client to identify the social and environmental risks of a project and the Bank makes sure that appropriate measures are in place to avoid or mitigate the risks.⁴²⁵

The ESF mandates the clients to implement resource efficiency when it is financially or otherwise feasible. Resource efficiency covers energy, water, and other material consumption.⁴²⁶

⁴²² AIIB, 2022

⁴²³ AIIB, 2018

⁴²⁴ AIIB, 2016

⁴²⁵ AIIB, 2021

⁴²⁶ AIIB, 2021

Pollution prevention and control technologies applied to a project need to be consistent with international standards. The World Bank's EHS guidelines, for example, are recommended to be used for this purpose.⁴²⁷

The GHG emissions arising from the project need to be evaluated. When economically or technically feasible, the projects should consider implementing low-carbon technologies, reducing emissions, improving energy efficiency, or using renewable energy.⁴²⁸

The ESF essentially addresses environmental and social risks and impacts of projects in their preparation, identification, and implementation. The national environmental and social policies are applied if they are stricter than the AIIB's. When co-financing projects with other MDBs or other institutions, the AIIB may use the environmental and social policies of the co-financier.⁴²⁹

3.10 European Bank for Reconstruction and Development

The Energy Sector Strategy (ESS) for 2019-2023 outlines the European Bank for Reconstruction and Development's (EBRD's) approach to energy sector operations. According to the Strategy, the Bank strives to increase electrification, decarbonize electricity, improve energy efficiency, promote fuel switching, increase renewable energy generation capacity, and decrease the associated costs, and promote natural gas as a transition fuel.⁴³⁰

Natural gas projects are financed with the objective of supporting the variable nature of renewables, and to replace coal and oil. The investments in natural gas projects can be facilitated when lower carbon energy sources are not feasible, and

⁴²⁷ AIIB, 2021

⁴²⁸ AIIB, 2021

⁴²⁹ AIIB, 2021

⁴³⁰ EBRD, 2018

the projects are not subject to becoming stranded assets. Shadow price of carbon is taken into account in the economic assessment of the project. The project must be consistent with country's NDCs and Bank's Environmental and Social Policy.⁴³¹

Additionally, the design has to be technologically flexible. Technological flexibility of the design means that the power plant can be retrofitted to reduce emissions in the future. Examples include operational changes from baseload to peaking capacity, adoption of CCS, or repurposing natural gas infrastructure to be used for biogas and hydrogen.⁴³²

The EBRD does not invest in coal projects, oil exploration, or upstream oil development projects, except projects which reduce GHG emissions or flaring. The Bank does not finance new nuclear power plants either. However, safety improvements, radioactive waste management, and decommissioning of existing nuclear power plants are supported.⁴³³

The Bank does not invest in coal related activities, including related transport, district heating, or electricity production. Although, the Bank can finance district heating companies, provided that the investment is not related to coal-based production. The Bank finances efficiency and environmental upgrades of some of the existing coal-fired assets if they are compliant with Best Available Techniques and EU emission limits.⁴³⁴

Shadow carbon pricing is applied to all GHG intensive projects as part of the financial evaluation of a project. GHG intensiveness is defined as an annual release of

⁴³¹ EBRD, 2018

⁴³² EBRD, 2018

⁴³³ EBRD, 2018

⁴³⁴ EBRD, 2018

100 000 tonnes of CO₂eq. The carbon price considered in the economic assessment is 40-80 US dollars per one tonne of CO₂eq. The Bank uses the economic assessment as part of their project approval evaluation process.^{435,436}

The EBRD lists a few innovations of the energy sector: fugitive methane emission detection in the upstream via sensors and in the midstream operations via drones, waste to power, biomass to fuels, bifacial solar panels, CCUS, hydrogen, chemical batteries and thermal storage, ultra-high-voltage cables, mini grids, and smart meters. The Bank supports these innovations through investments, policy engagement, green bonds, the Green Innovation Programme, and Climate Innovation Vouchers.⁴³⁷

According to the Bank's Environmental and Social Policy (ESP) the financed projects must comply with the EU's environmental principles and practices independent of the project's host country. The ESP outlines ten Performance Requirements. Performance Requirement 3 discusses Resource Efficiency and Pollution Prevention and Control.⁴³⁸

Under PR3, the GHG emissions of a project need to be avoided and minimized when technically and economically feasible during the implementation and operation of the project. Such measures include, for example, utilizing low carbon energy sources or reducing fugitive emissions and gas flaring, similar to the World Bank's Performance Standards. If the project's annual GHG emissions exceed 100 000 tonnes of CO₂eq, the emissions need to be quantified and reported with the practices of the EBRD's Protocol for Assessment of Greenhouse Gas Emissions.

⁴³⁵ EBRD, 2018

⁴³⁶ EBRD, 2020

⁴³⁷ EBRD, 2018

⁴³⁸ EBRD, 2019

The quantification includes direct emissions from all activities of the project, and indirect emissions from the production of energy used by the project.⁴³⁹

The EBRD establishes in its' Green Economy Transition (GET) 2021-25 that the Bank will dedicate half of its' total finance to green finance by 2025. GET also expresses the Bank's target to reduce GHG emissions by 25 million tonnes annually.⁴⁴⁰

3.11 European Investment Bank

The European Investment Bank (EIB) outlines in its' Energy Lending Policy (ELP) that the Bank does not finance any unabated fossil fuel energy projects, including natural gas. The decision covers all geographical locations, even beyond the EU. ELP reflects the EU's energy targets and policies.^{441,442}

The European Investment Bank focuses on four themes in their energy sector operations. The themes are energy efficiency, low-carbon supply, innovation, and enabling infrastructure.⁴⁴³

Energy efficiency is the most cost-effective means of achieving the climate and energy goals of the EIB. Buildings, as well as heating and cooling are priorities in the energy efficiency realm. The EIB and the European Commission deployed the Private Finance for Energy Efficiency initiative to increase energy efficiency investments.⁴⁴⁴

⁴³⁹ EBRD, 2019

⁴⁴⁰ EBRD

⁴⁴¹ EIB

⁴⁴² EIB, 2019

⁴⁴³ EIB

⁴⁴⁴ EIB

The EIB partakes in the pursuit of the EU's European Green Deal targets. The Bank shares the EU's goal of reaching 32 per cent renewables in the energy mix by 2030. (The target is increased to 40 per cent when the revision of RED is approved.) The goal is reached by doubling the generation capacity of renewable electricity. In addition to electricity production, the share of low-carbon gases (biogas and hydrogen), renewable heat (biomass and geothermal), and low-carbon fuels are increased to achieve the goal. The topic was thoroughly explored previously in a dedicated chapter.^{445,446}

The Bank supports innovation and innovative energy infrastructure. Innovative energy infrastructure includes decentralized energy production, electric vehicles, innovative business models, and energy storage.⁴⁴⁷

The EIB invests in enabling infrastructure to integrate variable renewable energy and to foster cross-border interconnections. The grid investments are expected to grow over time and increase in significance due to electrification. In addition to traditional transmission and distribution, the Bank invests in storage and off-grid systems.⁴⁴⁸

⁴⁴⁵ EIB

⁴⁴⁶ EIB, 2019

⁴⁴⁷ EIB

⁴⁴⁸ EIB

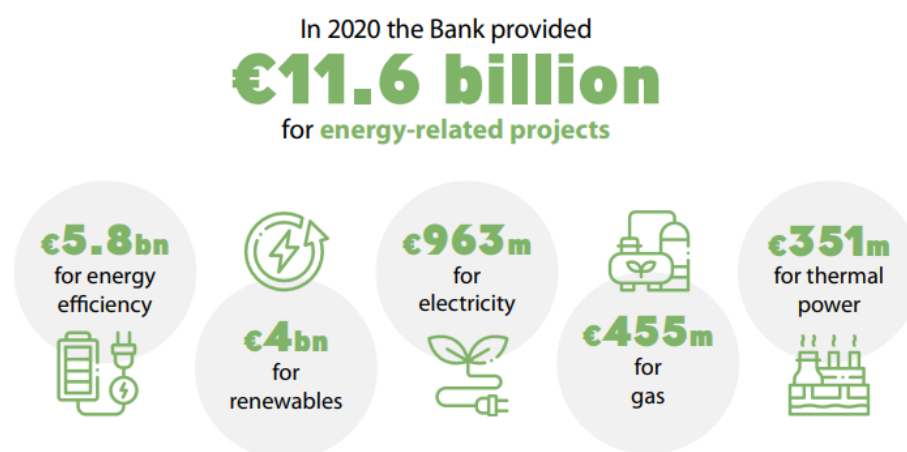


Figure 30. EIB Lending⁴⁴⁹

The Bank does not finance electricity, heat, or co-generation projects that emit more than 250 gCO₂eq/kWh. The emission limit of 250 gCO₂eq/kWh is also applicable to low-carbon energy sources and projects applying CCS. Unabated fossil fuel projects are not financed.^{450,451}

Industrial waste heat utilization projects are applicable for Bank finance as an energy efficiency improvement project. Energy efficiency gas-fired co-generation projects may be financed by the Bank as well, if it can be proven that the project is truly energy efficient and compliant with the EED. The project must result in 5 per cent annual primary energy savings, and the electricity generation of the project still has to result in less than 250 gCO₂eq/kWh emissions.⁴⁵²

⁴⁴⁹ EIB, 2021

⁴⁵⁰ EIB

⁴⁵¹ EIB, 2019

⁴⁵² EIB, 2019

The Bank thinks that natural gas can potentially provide short term GHG emission reductions when substituting oil and coal. Investments will occur even in the absence of the Bank's financing of such projects.⁴⁵³

Natural gas is intended to be replaced with low-carbon gases, such as synthetic gas, hydrogen, and biogas. The Bank finances the production of these gases, as well as related infrastructure to enable integration. The Bank only supports gas infrastructure projects which are intended to transport these low-carbon gases.⁴⁵⁴

The GHG emissions of biomass and low-carbon fuel production projects need to comply with emission limits set out in the EU Directive 2018/2001 when appraising such projects.⁴⁵⁵

The technologies that are not widely deployed yet, may be financed by the Bank if it deems the long-term economic outcomes to justify the high initial costs. An example of this is hydrogen.⁴⁵⁶

The EIB's Environmental and Social Standards frame the Bank's requirements to manage environmental and social risks of a project. Standard 3 covers resource efficiency and pollution prevention, and standard 5 covers climate change.⁴⁵⁷

The objective of standard 3 is to facilitate resource efficiency and promote circular economy through the use of Best Available Techniques (BAT). Pollution prevention and control is done through compliance with Industrial Emissions Directive (IED) for projects located in the EU.⁴⁵⁸

⁴⁵³ EIB, 2019

⁴⁵⁴ EIB, 2019

⁴⁵⁵ EIB, 2019

⁴⁵⁶ EIB, 2019

⁴⁵⁷ EIB, 2022

⁴⁵⁸ EIB, 2022

Standard 5 outlines the mandatory climate change mitigation and adaptation measures of a project. The projects can be aligned with the European Green Deal, the European Climate Law, National Energy and Climate Plans (NECPs) and National Adaptation Plans, among others. Information on the emitted GHG emissions and the project's alignment with climate resiliency need to be provided to the Bank.⁴⁵⁹

⁴⁵⁹ EIB, 2022

4 CONCLUSIONS

The urgency of mitigating GHG emissions is evident from the climate change induced effects already experienced all around the world, and the future projections of effects yet to be experienced. The carbon budget of limiting global warming to 1,5 degrees would be used up by 89 per cent in 2030 if all NDCs announced before COP26 were implemented. The carbon budget to limit warming to 2 degrees would be used up by 39 per cent in 2030. The estimation raises concern and entails that immediate action needs to be taken to limit emissions before the year of 2030, especially if the warming would like to be kept under 1,5 degrees.⁴⁶⁰

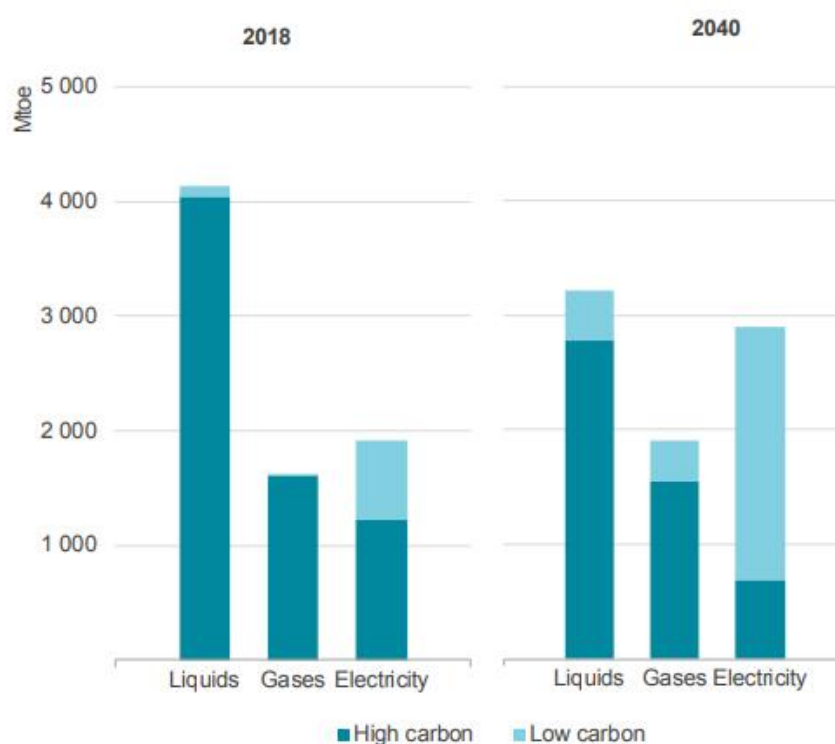
Many regions around the world have still not hit their GHG emission peak, because energy consumption tends to increase with industrialization and country development. On top of that, the people who still live without access to electricity are yet to be accommodated. The current consensus is that coupling energy efficiency measures with increased low-carbon energy production is the primary way of tackling the GHG emissions arising from increased and existing energy consumption.⁴⁶¹

While energy efficiency improvements conserve energy, and thus extend the energy supply, new production capacity will still be needed, and existing fossil fuel usage replaced. Extending the low-carbon energy production capacity has been assigned to fulfil this dual purpose. Increases in solar and wind power generation capacity are expected to rise to the task in particular.

⁴⁶⁰ UNFCCC, 2021

⁴⁶¹ Ritchie, and Roser, 2020

Final energy consumption by carrier in 2018 and 2040 in the SDS



Note: Low-carbon gases include low-carbon hydrogen, biomethane and low-carbon synthetic methane, along with gas-based carbon capture, utilisation and storage (CCUS) used in large-scale industry.

Figure 31. Final Energy Consumption by Carrier in 2018 and 2040 in the SDS⁴⁶²

As seen from the Figure 31, the future of energy is going to rely more on electricity. Electricity is the easiest sector to decarbonize, which means that electricity is going to take over other forms of energy. Gas and liquids are going to be replaced with electricity, for example in industrial processes and the heating of buildings. However, electrification cannot be extended to all energy sectors in a feasible manner. Other energy sources will still be needed in hard-to-abate applications

⁴⁶² International Energy Agency, 2020

and energy sub-sectors. For example, the long-distance transport and some industrial processes cannot be powered by electricity. These sectors will be decarbonized with hydrogen, low-carbon fuels, CCUS, and other technologies, in the future.

Nowadays four fifths of the energy used is fossil-based. According to IEA's projections, fossil fuels would only account for 20 per cent of energy consumption in the net zero pathway for the year of 2050. Coal has been excluded from financial support by many institutions already, and the utilization of other fossil fuels is gradually decreased and replaced with other energy sources across energy sectors. Natural gas has gained recognition as the transition fuel, which initially replaces oil and coal, before the gas infrastructure and assets can be used by low carbon fuels.⁴⁶³

The transition from fossil fuels to low-carbon fuels is highly dependent on policy tools and reforms which incentivize the use of these fuels. In addition to policy incentivisation, the production costs of power-to-X and other low-carbon fuels need to be brought down through extended production capacity and economies of scale. The current production capacities are not enough to supply the emerging end-use sectors of these fuels.⁴⁶⁴

According to the International Energy Agency, up until 2030, the required GHG emission reductions can be largely achieved by utilizing already commercialized and existing technologies. However, after the year of 2030, new technologies which have not entered the market yet need to be deployed at large scale. Climate neutrality will not be achieved by 2050, or global warming limited to 1,5 degrees without the deployment of these emerging technologies.⁴⁶⁵

⁴⁶³ International Energy Agency, 2021

⁴⁶⁴ Oeko-institut, 2021

⁴⁶⁵ International Energy Agency, 2021

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5 APPENDIX

Renewables have penetrated the electricity sector well in the last ten years, while much slower progress can be detected in heat and transport sectors. The energy sector took a hit from the COVID-19 pandemic. Decarbonizing the electricity sector, however, was kept on the right track, thanks to policies and declining prices of technologies. Much can be alluded to long-term contracts, priority access to the grid, low marginal costs, and new installed capacity. Even though renewable sources of energy have increased over the years, the total energy consumption has increased simultaneously, resulting in the share of renewables appearing to be stagnant at around 17 per cent. IEA estimates that renewable energy constitutes 25 per cent of total energy consumption in 2030.⁴⁶⁶

Solar and wind energy have had the most significant increase in total energy consumption leading up to 2018. Even though renewables are well represented in the electricity sector, electricity covered only 21 per cent of total energy consumption in 2018. Heat sector contributed to 47 per cent and transport 32 per cent in 2018.⁴⁶⁷

Promoting the usage of renewables, energy efficiency, and decreasing fossil fuels in the heat sector is regarded with policies very little. About 75 per cent of heat is sourced from fossil fuels. The percentage of renewables in the heat sector is around nine, when traditional uses of biomass is excluded. The progress report suggests that policymaking should promote technologies like sustainable gases and biomass, solar thermal, and geothermal heat in order to decarbonize the heat sector. Electrification would be a viable option to decarbonize the heat sector as

⁴⁶⁶ IEA, IRENA, UNSD, World Bank, WHO, 2021

⁴⁶⁷ IEA, IRENA, UNSD, World Bank, WHO, 2021

well. Clear and coherent policies are important in directing investments to the sustainable path in heating and cooling. Only 49 countries had supportive policies for sustainable heating and cooling, and the number has remained nearly unchanged for years. Policies to support the end of fossil fuel utilization, increased energy efficiency, and renewables, are needed to address the emissions of heating and cooling.⁴⁶⁸

The follow-up report proposes strategies to accelerate the decarbonization of the heat sector, one of which is replacing fossil gases with renewables, such as green hydrogen, biomethane and biogas. Some of the renewable gases, like biomethane, can utilize the existing gas infrastructure, decreasing the need for investments. Policies, subsidies, and investments would be needed to promote the transition. Supportive policies create security and confidence in sustainable finance. Many countries decided to end financial support for unabated fossil fuels in COP26. The pledge is a step towards reaching the goals of SDG7.⁴⁶⁹

Emergence of electric vehicles has led to progress in decarbonizing the transport sector. Biofuels, mainly ethanol and biodiesel have also increased the share of renewables in transport sector. The pandemic had an unfortunate impact on biofuels due to reduced demand for fuel altogether. However, over seventy countries have policies in place to support biofuel. Electric vehicles' support is highly market-driven in these countries as well. The countries are forecasted to experience an increase in the share of renewables in the transport sector. The countries which do not have promoting policies in place will not experience such growth, alluding to the importance of policies.⁴⁷⁰

⁴⁶⁸ IEA, IRENA, UNSD, World Bank, WHO, 2021

⁴⁶⁹ COP26, 2021

⁴⁷⁰ IEA, IRENA, UNSD, World Bank, WHO, 2021

The target to increase energy efficiency is 2,6 per cent annually by 2030. IEA estimates that the improvement will be hindered to an annual improvement of 2 per cent until 2025. The goal is most likely not reached.⁴⁷¹

While renewable energy is mainly driven by private investments, developing countries have a different story to tell. Low-carbon energy is heavily funded by public finance in developing countries. It is essential to direct international public finance to developing countries in order to reach the SDG7 goals. Progress report shows that a large portion of international public financial flows go to a few specific countries. Financial flows directed to 46 least developed countries only amounted to a fifth of the total finance. De-risking investments to certain countries and sectors is an important tool to attract private finance and help these countries reach goals of SDG7. If public finance could be attracted to capacity projects, public finance could focus on financing infrastructure upgrades and system flexibility, like energy storage.⁴⁷²

⁴⁷¹ IEA, IRENA, UNSD, World Bank, WHO, 2021

⁴⁷² IEA, IRENA, UNSD, World Bank, WHO, 2021