

GLOBAL ENERGY PERSPECTIVES TO 2050

Introduction

Global climate change is a huge challenge for all the humanity. For many decades, the rise in energy consumption has been closely related to the rise in carbon dioxide emissions, which contributes to the heating of the planet's atmosphere. Maintaining the trend towards an increase in anthropogenic greenhouse gas emissions will be accompanied by an increase in the level of the world ocean, the intensification of hurricane activity and the melting of permafrost, i.e. huge losses for the society.

Despite the growth in electricity generation from renewable sources in recent years, fossil fuels account for more than 80% of the world's primary energy consumption. The recent sharp rise in European gas prices is a clear indication of the continued dependence of industrialized countries on fossil fuels.

The COVID-19 pandemic has become a new challenge for the global economy. As a result of the quarantine restrictions, demand in many industries has dramatically decreased, the model of consumer behavior has changed – many employees have switched to distant work, global supply chains of goods have suffered. After development of vaccines the economies of most countries began to recover, which requires additional amounts of energy supply.

The COVID-19 pandemic and the changes in the climate policy of the leading industrial countries in 2020 and 2021 led to significant adjustments of LUKOIL's energy scenarios. The updated demand forecasts for major energy carriers were made considering the most relevant climate targets after the 26th session of the Conference of the Parties (COP 26) to the UN Framework Convention on Climate Change held in Glasgow in November 2021.

Unlike previous reports, which were mainly focused on the analysis of liquid hydrocarbons market trends, the 2021 report attempts to develop balanced scenarios for the whole global energy sector. A broader industry coverage makes it possible to better describe the main challenges that LUKOIL faces and possible directions for company development.

Three scenarios for global energy perspectives were developed within the report. The "Evolution" scenario assumes the ongoing development of global energy markets within the framework of the current international energy policy and national programs, considering existing technological capabilities. The "Equilibrium" scenario is based on a balance between achieving climate goals and economic development. The "Transformation" scenario assumes a radical restructuring of global energy and industry as well as carbon neutrality of the leading economies by 2050. Such a scenario approach allows to outline more clearly the scale of uncertainty associated with the most important trends in the development of global energy.

A separate section of the report is devoted to the Russian energy sector. It shows the scenarios of energy consumptions and the corresponding trajectories of greenhouse gas emissions reduction, as well as analyzes the potential for emissions reduction in Russia using various methods.

The background is an abstract composition of numerous small, out-of-focus light points in shades of blue and white, creating a bokeh effect. These points are arranged in a way that suggests a sense of depth and movement, with some points appearing as bright, sharp highlights while others are softer and more blurred. A solid red horizontal banner is positioned in the lower-left quadrant of the image, providing a stark contrast to the light, airy background.

GLOBAL ENERGY

The COP26 Climate Conference has recorded an increase in the ambitions of leading industrial countries to reduce greenhouse gas emissions

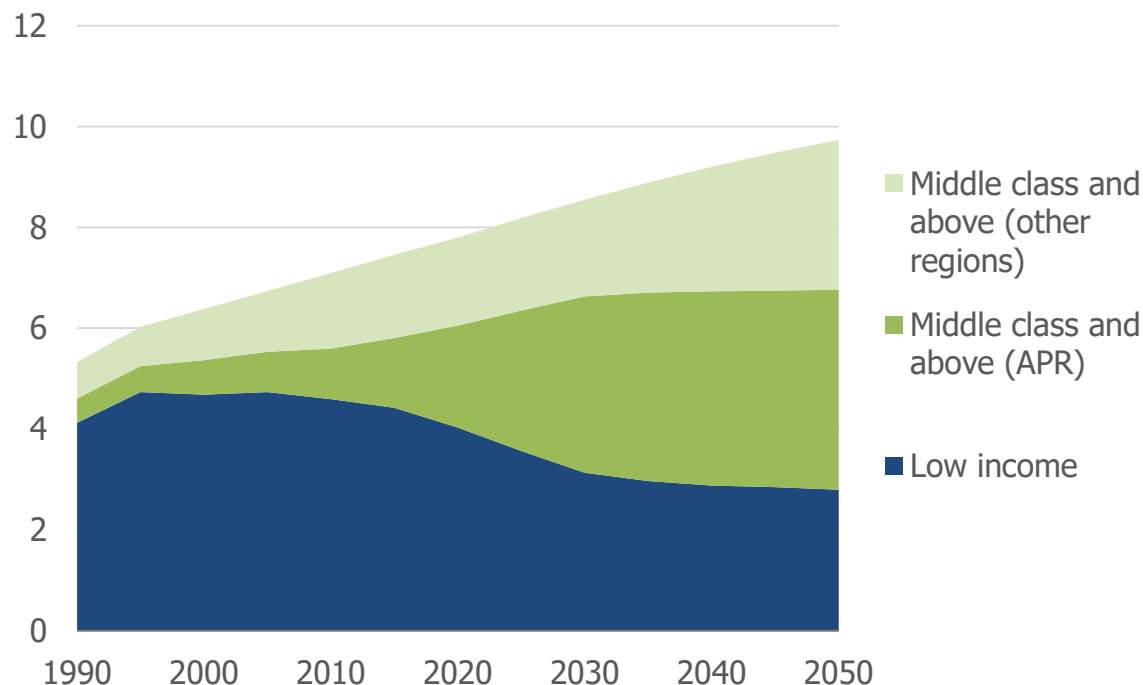
The stated goals of leading economies to reduce greenhouse gas emissions

Country	 China	 USA	 EU	 India	 Russia
Emissions in 2020*	14 Gt CO ₂ e	6 Gt CO ₂ e	3,2 Gt CO ₂ e	2,9 Gt CO ₂ e	2 Gt CO ₂ e
Interim goal	>65% reduction of CO ₂ emissions per unit of GDP by 2030 to the level of 2005 Passing the peak of emissions by 2030	50-52% reduction of greenhouse gas emissions by 2030 from the level of 2005 (including land use and forestry)	≥55-60% reduction of greenhouse gas emissions from the 1990 level by 2030	33-35% reduction of GDP carbon intensity from the level of 2005 by 2030	70% from the level of 1990 to 2030, taking into account the maximum possible absorption capacity of forests and other ecosystems
Target year for achieving climate neutrality	2060	2050	2050	2070	2060

* Greenhouse gas emissions without absorption in land use and forestry

The recovery of global recovery will be accompanied by an increase in energy consumption

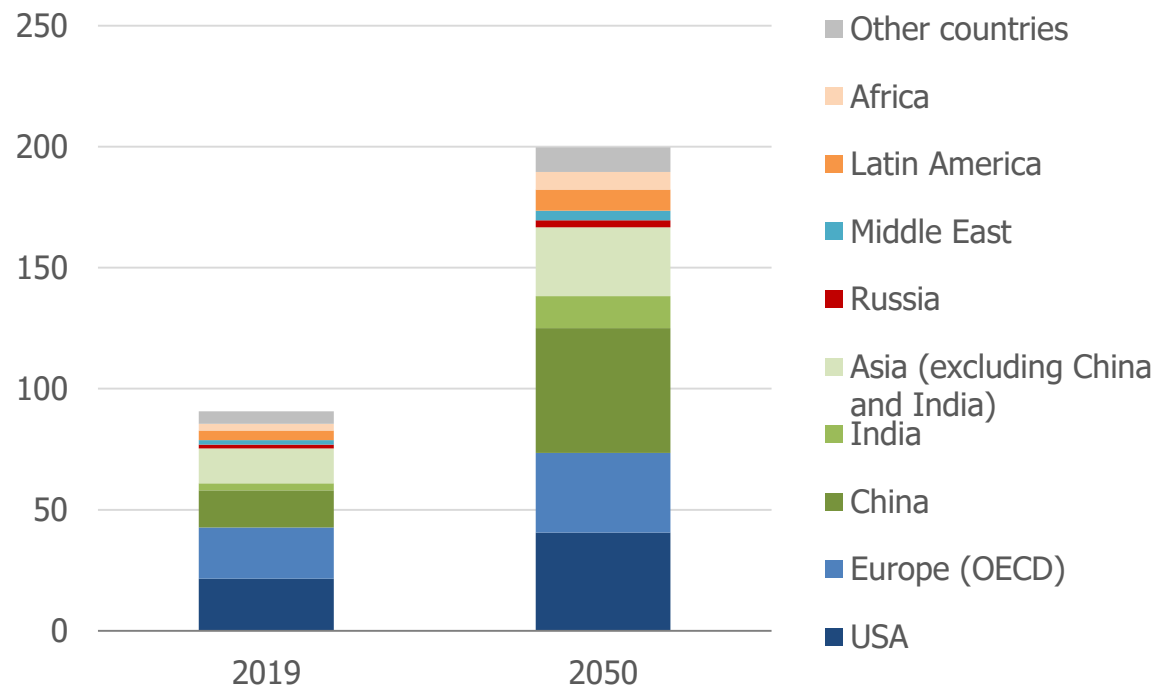
Global population and consumer class, bln



Source: UN, World Data Lab

- ▶ According to UN estimates, the world population will increase by 2 billion people by 2050
- ▶ Population growth will be accompanied by urbanization and the growth of the consumer class
- ▶ By 2050, the consumer class will be 6.9 billion people (about 70% of the world's population)

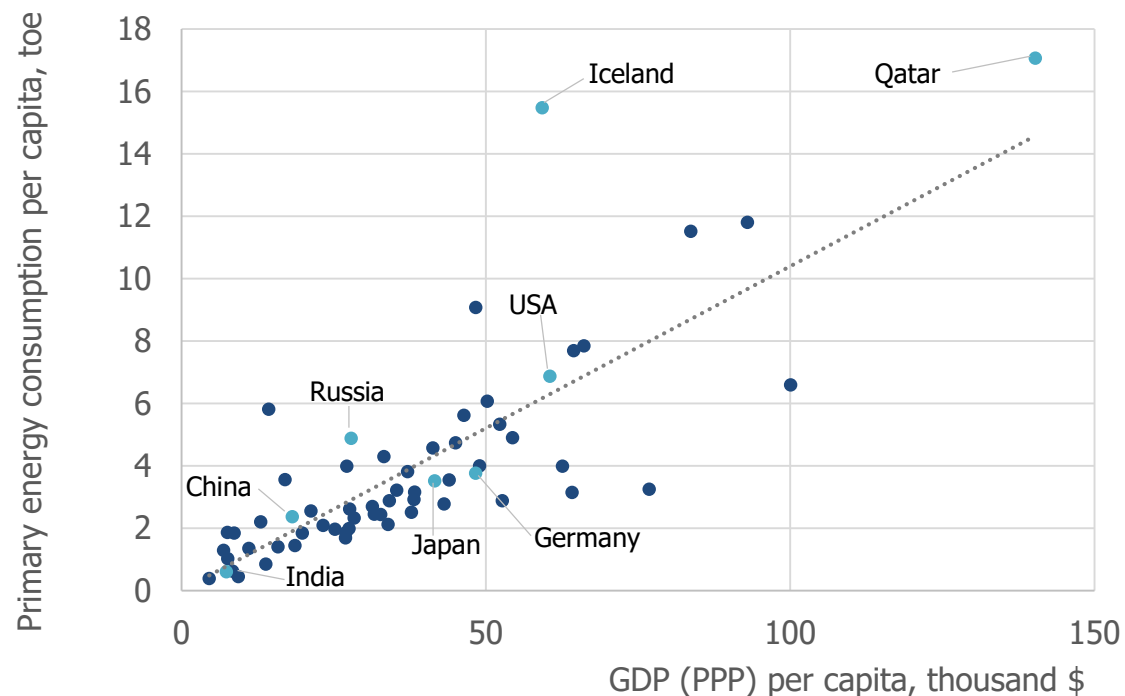
Global GDP by region, \$ tln 2019



- ▶ Global GDP will grow by more than 2 times by 2050
- ▶ The largest GDP increase is expected in the countries of the Asia-Pacific Region
- ▶ About half of the world's GDP by 2050 will be made in Asian countries

For sustainable development the world needs more energy, but less emissions

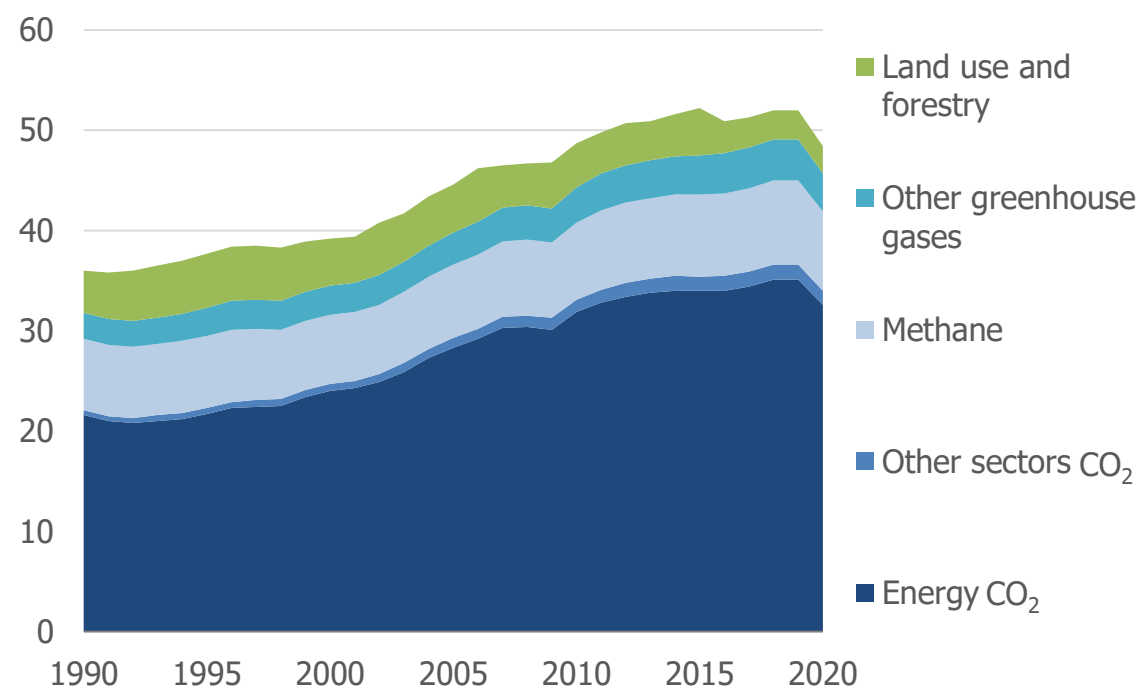
Primary energy consumption and GDP by country in 2019



Source: Our World in Data

- ▶ Access to energy is a necessary condition for the development of global economy
- ▶ Countries with a high level of wealth consume, on average, more energy per capita than poor countries

Greenhouse gas emissions dynamics, Gt CO₂e

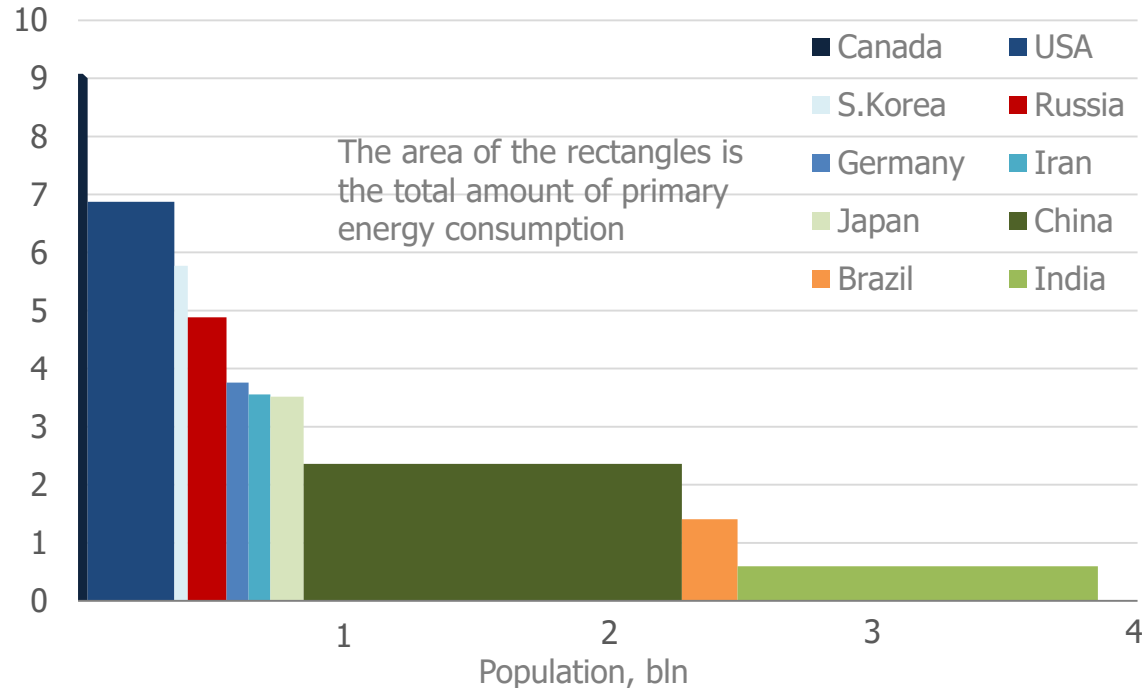


Source: Climate Watch, Climate Action Tracker

- ▶ The rise in energy consumption by developing countries has historically been accompanied by an increase in greenhouse gas emissions
- ▶ Providing the world's growing population with affordable energy and at the same time reducing greenhouse gas emissions is an extremely difficult task that requires breakthrough technological solutions

The high level of energy inequality in the world complicates the process of decarbonization of the economy

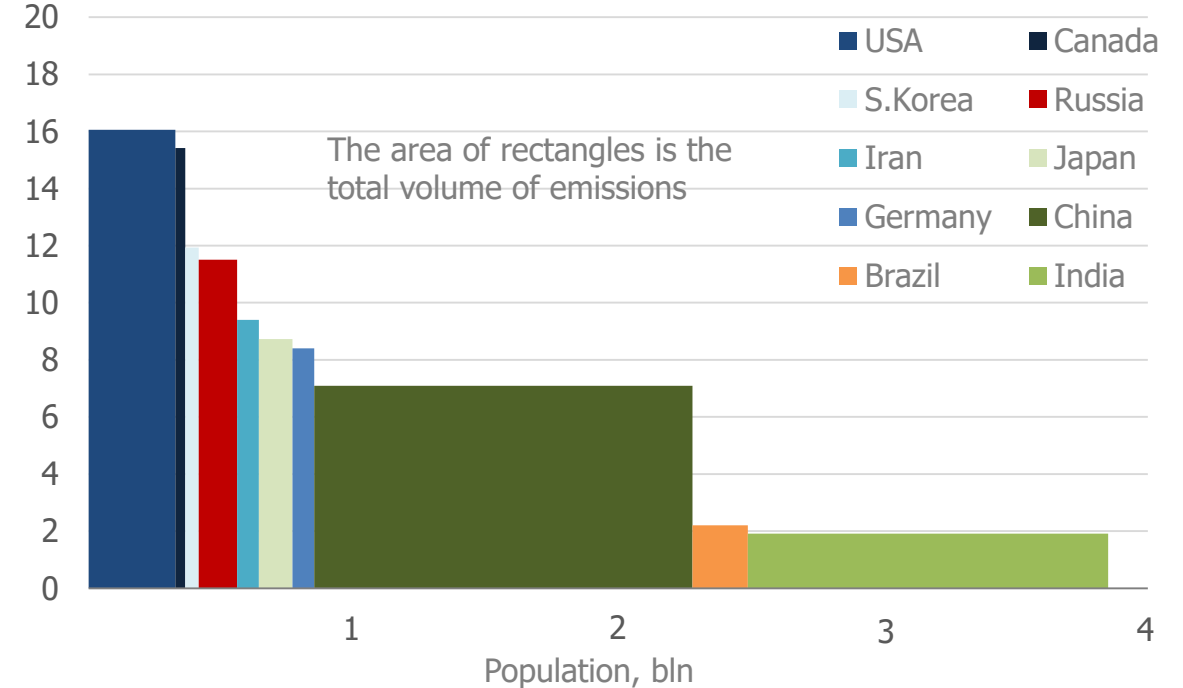
Primary energy consumption by the largest energy consumers in 2019, toe per capita



Source: Our World in Data

- ▶ The population of developed countries accounts for more than a third of the world's primary energy consumption
- ▶ Almost 1 billion people in developing countries do not have access to electricity
- ▶ According to the IEA, in 2020, due to the pandemic, about 90 million people lost the opportunity to pay for electricity

Energy CO₂ emissions of the largest energy consumers in 2019, t CO₂e per capita



Source: Our World in Data

- ▶ The gap in energy consumption per capita between developed and developing countries remains high, despite some reduction in the last decade
- ▶ Energy consumption per capita in developed countries is declining due to increased energy efficiency, while developing countries experience growth in energy consumption because of the rise in population wealth

To better understand the future structural changes in the global energy sector, we consider three scenarios

Evolution



- ▶ Priority of economic development and reduction of energy inequality
- ▶ Limiting greenhouse gas emissions within announced national emission reduction targets and existing technological capabilities
- ▶ Moderate rate of structural change in energy markets

Impact on climate



HIGH

Inflation



LOW

Energy accessibility



HIGH

Equilibrium



- ▶ The balance between achieving climate goals and economic development
- ▶ Achieving the Paris Agreement's goal of keeping global temperature growth below 2°C
- ▶ Consolidation of international efforts to achieve sustainable development goals

Impact on climate



MODERATE

Inflation



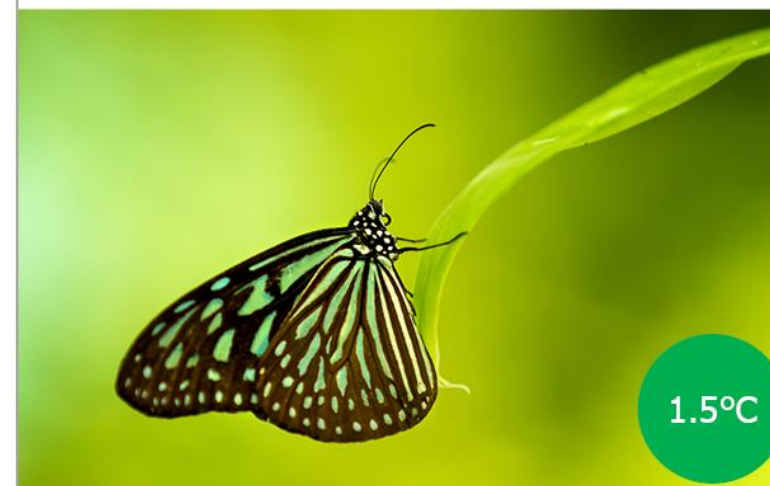
MODERATE

Energy accessibility



MODERATE

Transformation



- ▶ Focus on climate goals
- ▶ Unprecedented level of international cooperation and no restrictions on financing of climate projects
- ▶ Radical transformation of global energy and industry
- ▶ Carbon neutrality of leading economies by 2050

Impact on climate



LOW

Inflation



HIGH

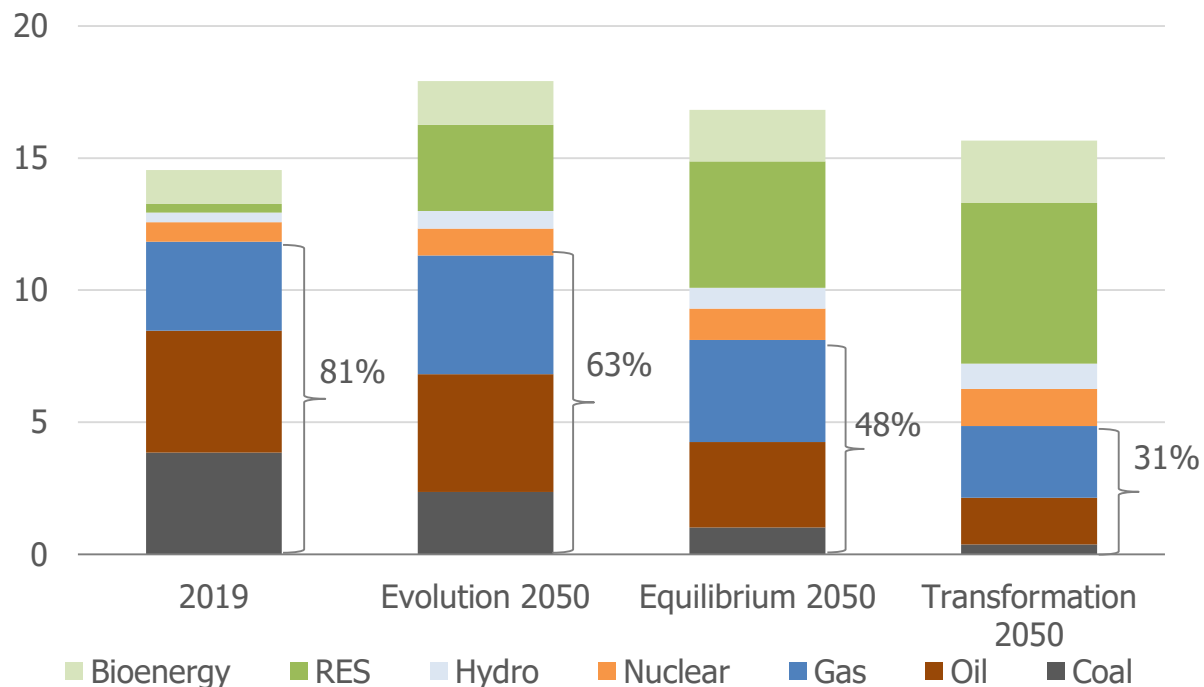
Energy accessibility



LOW

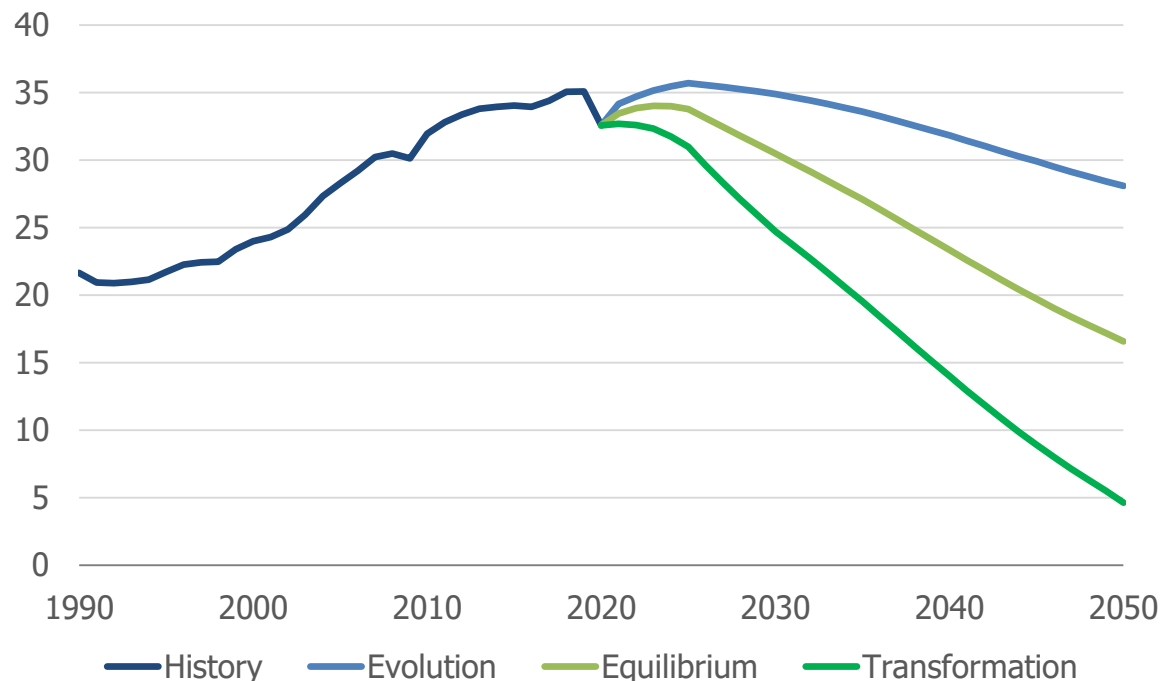
Primary energy consumption is expected to increase in all scenarios considered

Forecasts of primary energy consumption, Gtoe



- ▶ The structure of primary energy consumption will change towards an increase in the share of modern renewable sources in the energy mix
- ▶ The share of fossil fuels in primary energy consumption will decrease, while remaining significant

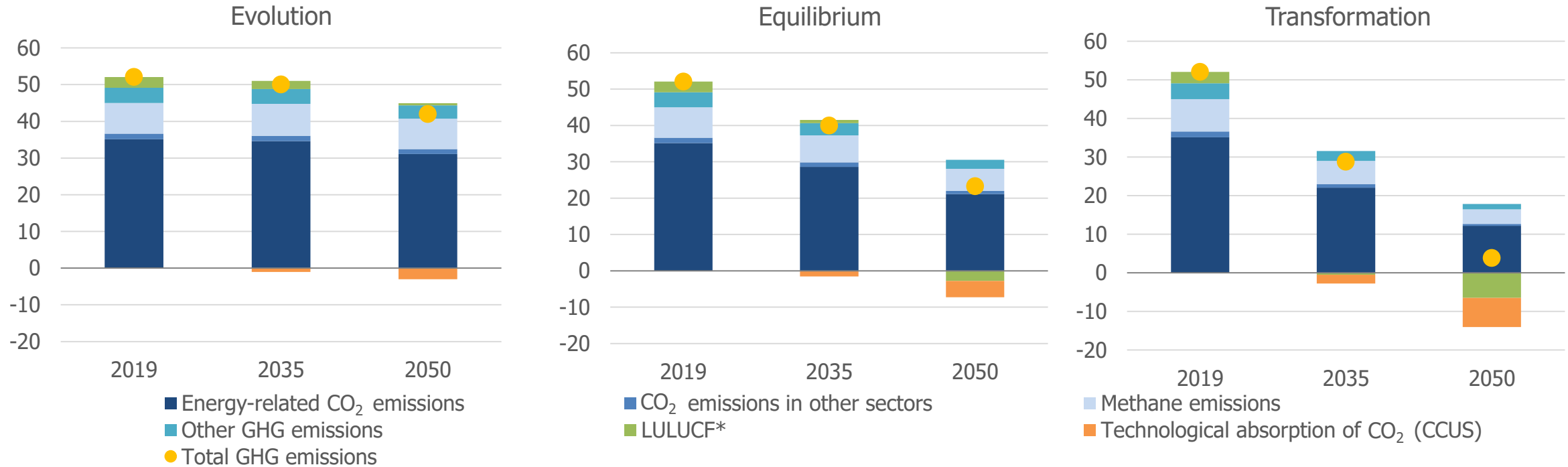
Energy-related CO₂ emissions, Gt CO₂e



- ▶ Changing the fuel structure of primary energy consumption will contribute to reducing energy emissions of greenhouse gases
- ▶ The rate of emission reduction will vary depending on the scenario

Achieving climate neutrality will require the use of both industrial and natural CO₂ absorbers

The structure of greenhouse gas emissions in various scenarios, Gt CO₂e

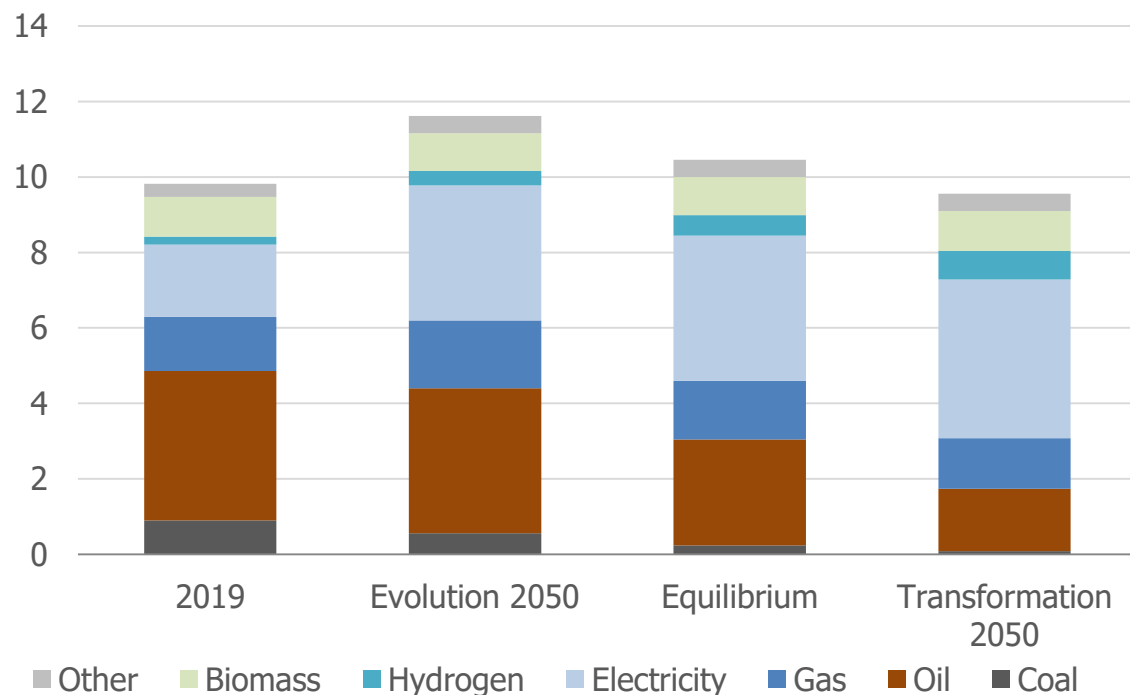


* LULUCF – land use land-use change and forestry

- ▶ Reducing greenhouse gas emissions requires profound technological changes not only in the energy sector, but also in other industries, agriculture and land use
- ▶ The use of carbon capture, utilization and storage technologies (CCUS and BECCS), as well as natural CO₂ sinks such as forests and wetlands, plays an important role in all scenarios
- ▶ By 2050, the volume of emissions absorption may range from 3 to 13 Gt of CO₂e per year

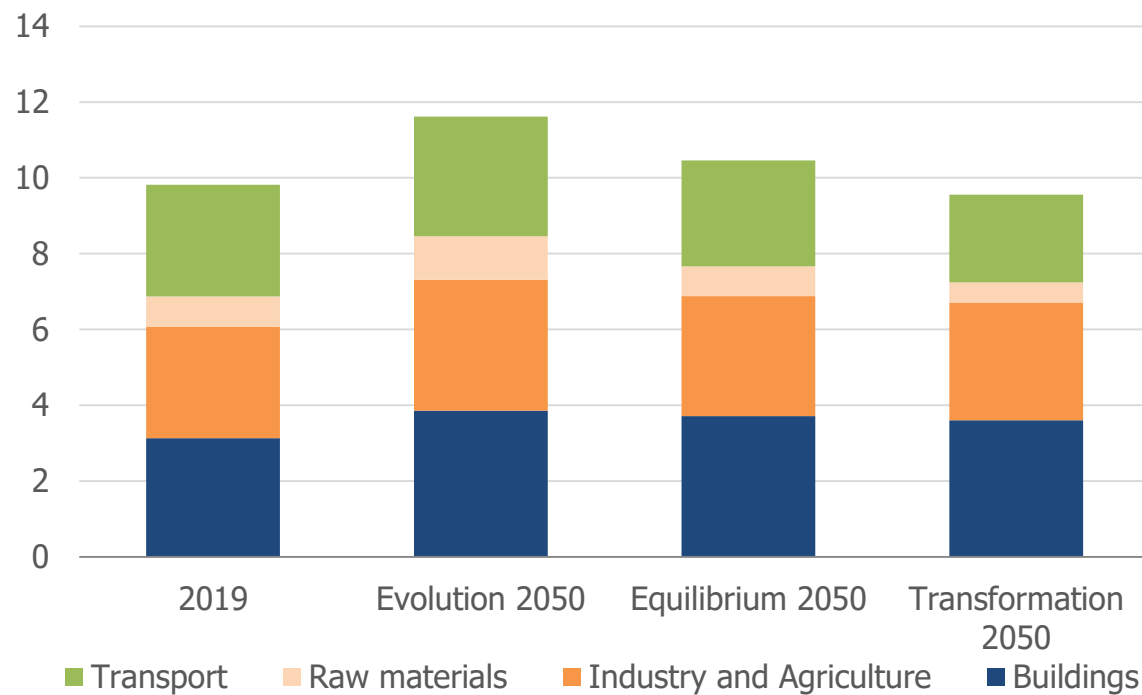
The share of electricity in final energy consumption is expected to increase

Final energy consumption by source, Gtoe



- ▶ Gradual electrification of the transport sector and industry will lead to an increase in the share of electricity in final energy consumption
- ▶ In the "Evolution" scenario, the share of electricity in final consumption will grow from the current 20% to 31%, and in the "Transformation" scenario – to 44%

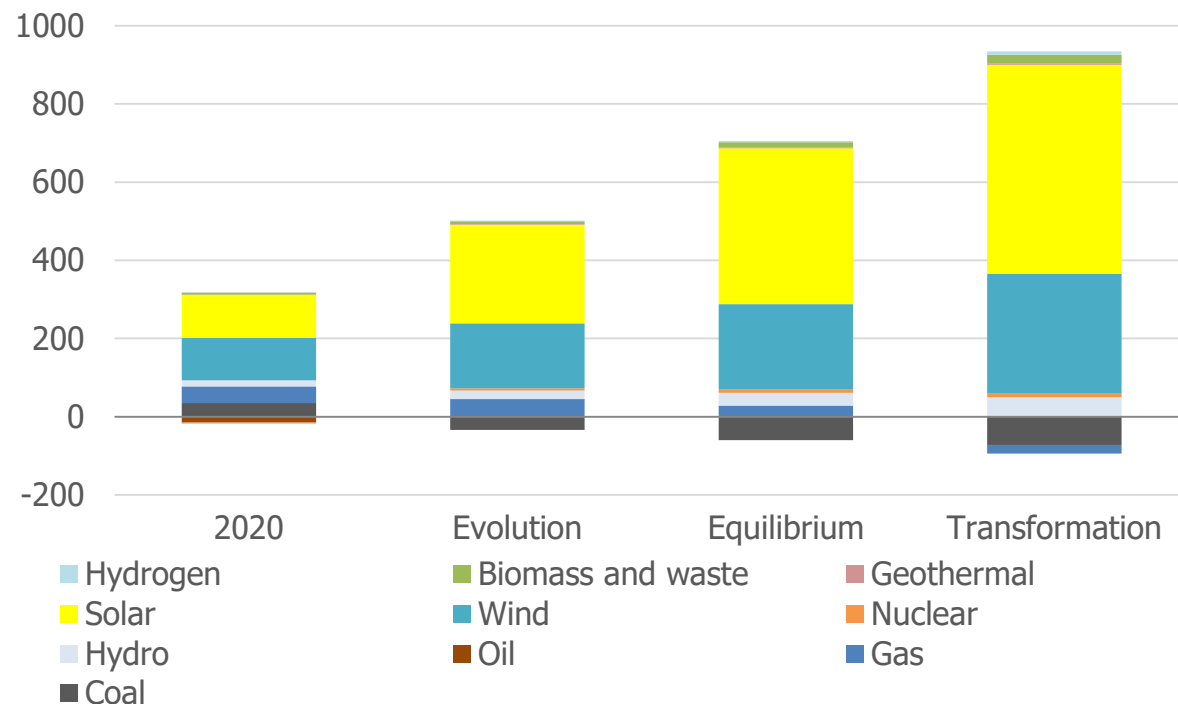
Final energy consumption by sector, Gtoe



- ▶ High rates of road fleet electrification will lead to a reduction in final energy consumption by the transport sector in the "Equilibrium" and "Transformation" scenarios
- ▶ Final energy consumption by buildings and industry will grow in all scenarios

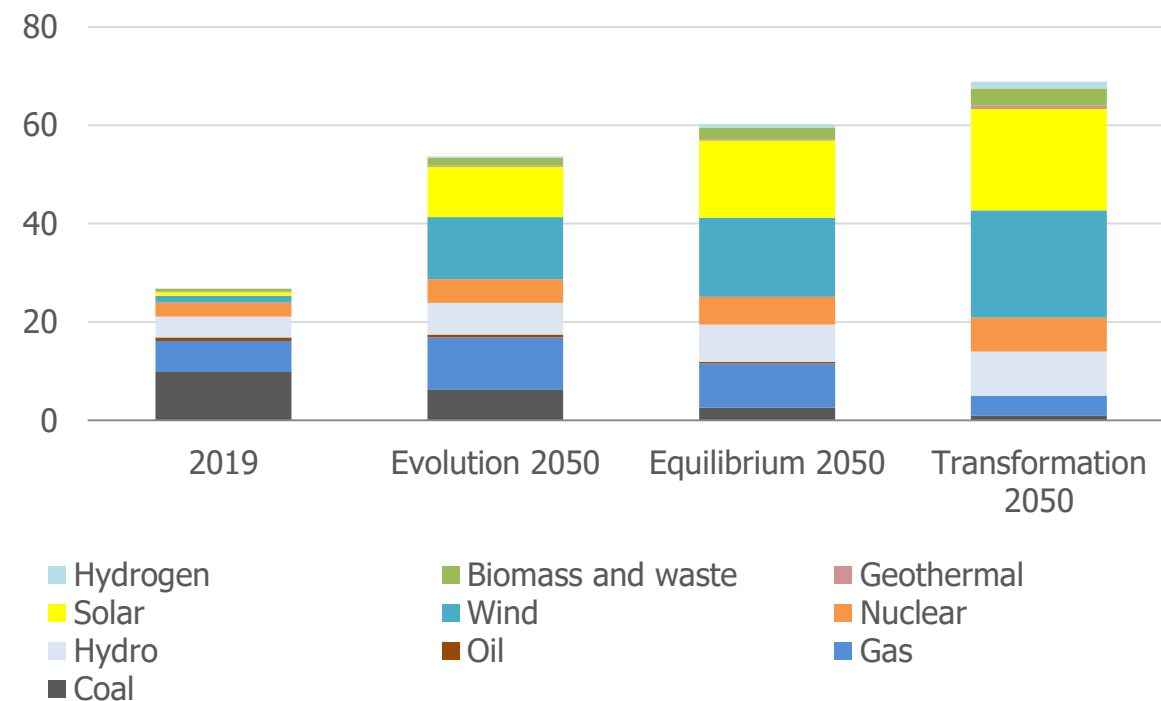
Reduction of emissions will require a large-scale restructuring of the power generation sector

Average annual net increase in power generation capacity, GW



- ▶ Main increase in power generation capacity will be provided by solar and wind power plants
- ▶ Coal generation will be gradually phased out
- ▶ Electrification of the transport sector will require generating capacity to grow faster than in previous decades

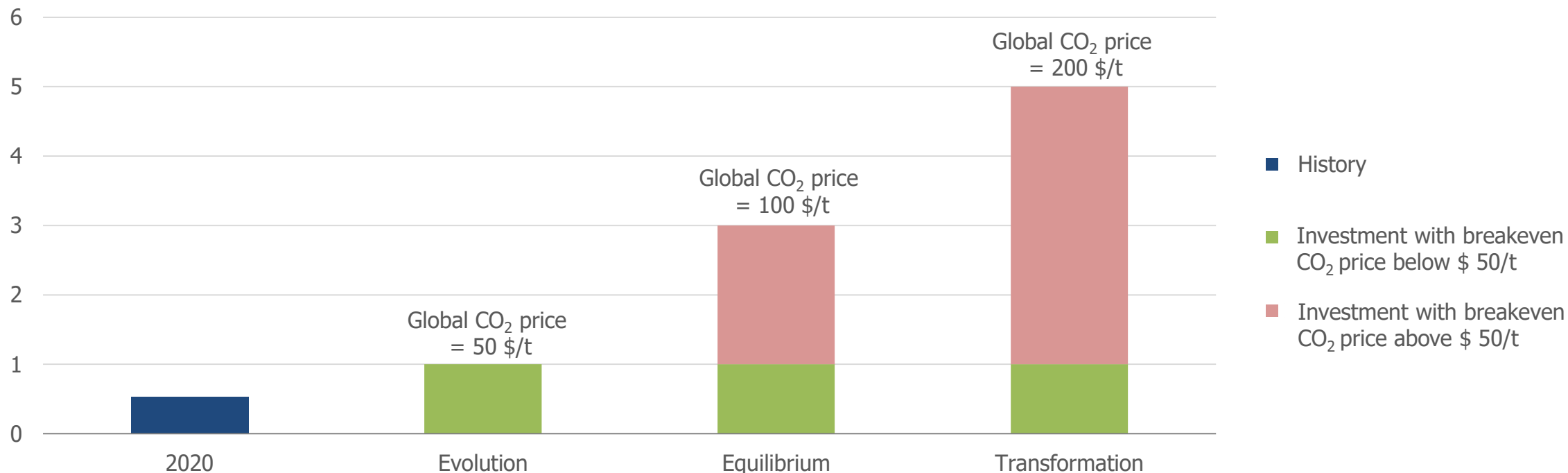
Forecasts of power generation by sources, thousand TWh



- ▶ In the "Evolution" scenario, RES (including hydropower) will account for about 60% of power generation by 2050
- ▶ In order to maintain a high share of renewable energy sources in the energy mix and ensure the stability of energy systems, significant infrastructure investments in electricity storage and distribution will be required

To achieve climate neutrality, a massive increase of investment in low-carbon energy is required

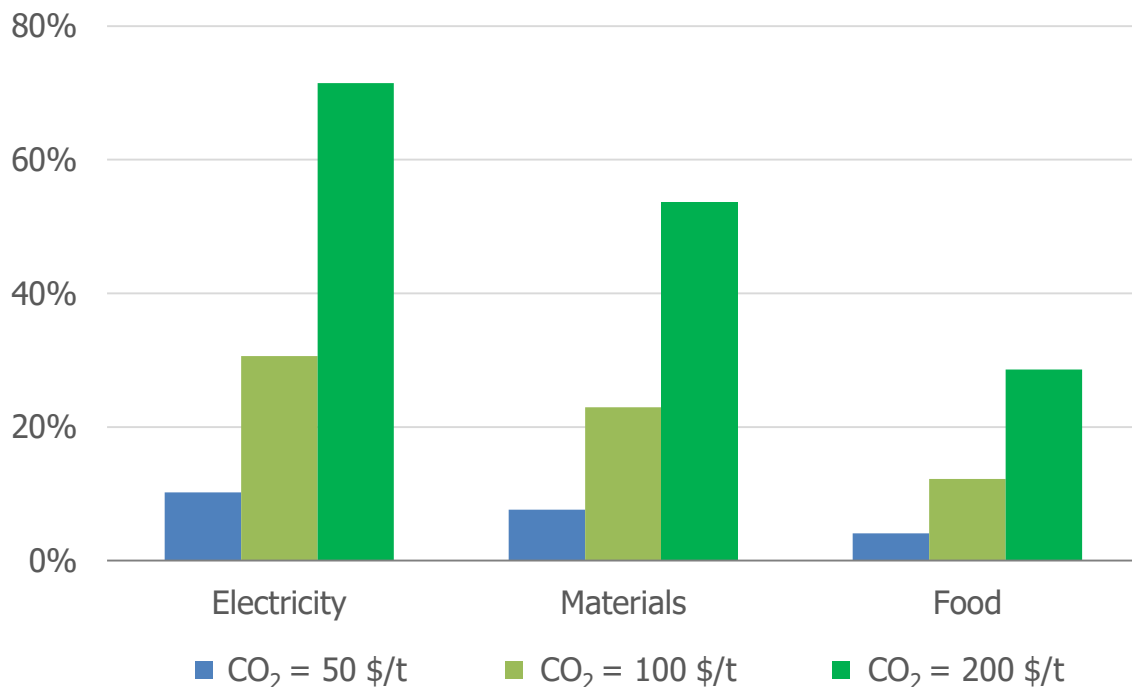
Average annual investment in low-carbon energy for 2021-2050, tln \$ 2020



- ▶ Decarbonization of energy sector will require additional investment in the electrification of industry and transport, production and consumption of new fuels (hydrogen and biofuels), energy efficiency improvement, CO₂ capture, utilization and storage, and forestry projects development
- ▶ In the "Evolution" scenario, the average annual investment in low-carbon energy should increase by 2 times compared to the current level, while the "Transformation" scenario assumes a tenfold increase in investment
- ▶ To ensure the return on investment in the "Transformation" scenario, the average price of CO₂ should increase up to \$ 200/t in constant prices

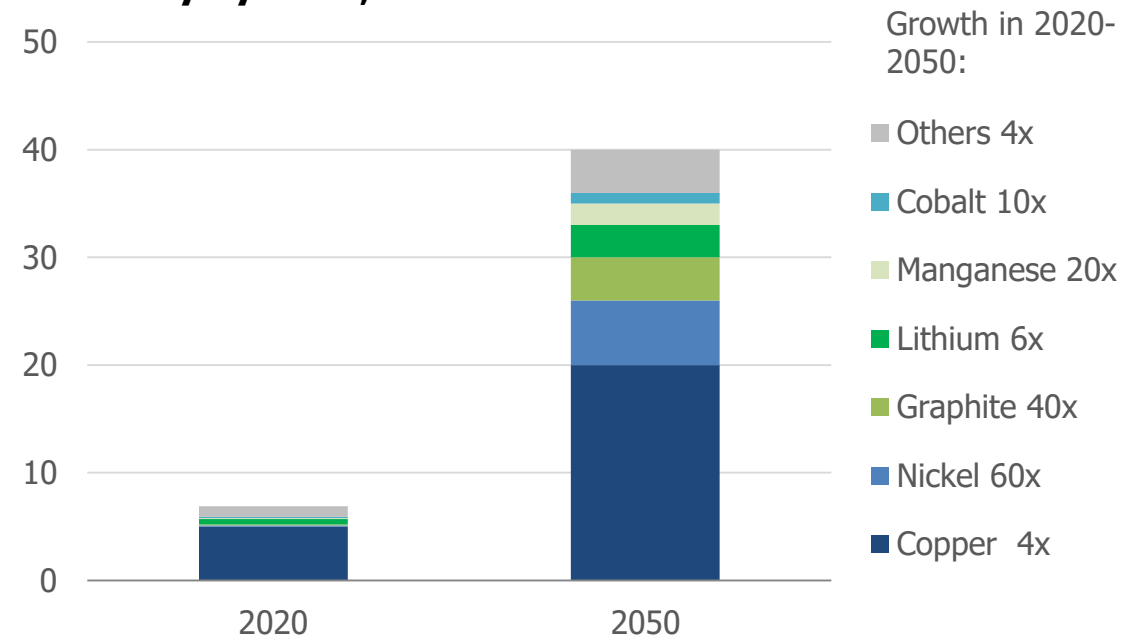
Decarbonization of energy sector can strengthen inflation

Price level changes for certain groups of goods in developed countries depending on the CO₂ price, %



- ▶ The introduction of a carbon price will lead to an increase in energy costs around the world
- ▶ According to our estimates, electricity prices in developed countries may increase by more than 70% if the carbon price is set at \$200/t

Demand for raw materials needed to ensure climate neutrality by 2050, Mt

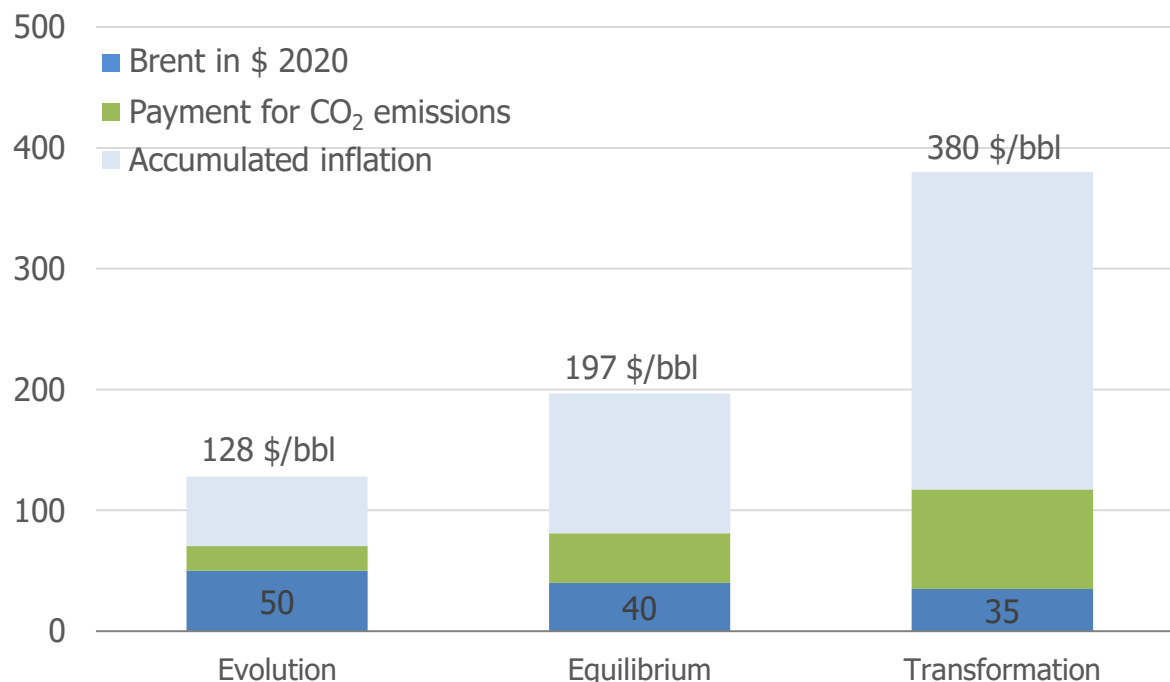


Source: IEA

- ▶ The shortage of a number of critical raw materials for low-carbon energy may also contribute to the growth of inflation
- ▶ According to the IEA estimates, in the Net zero emissions scenario (NZE), the demand for metals and raw materials necessary for the development of low-carbon energy will grow by almost 6 times by 2050

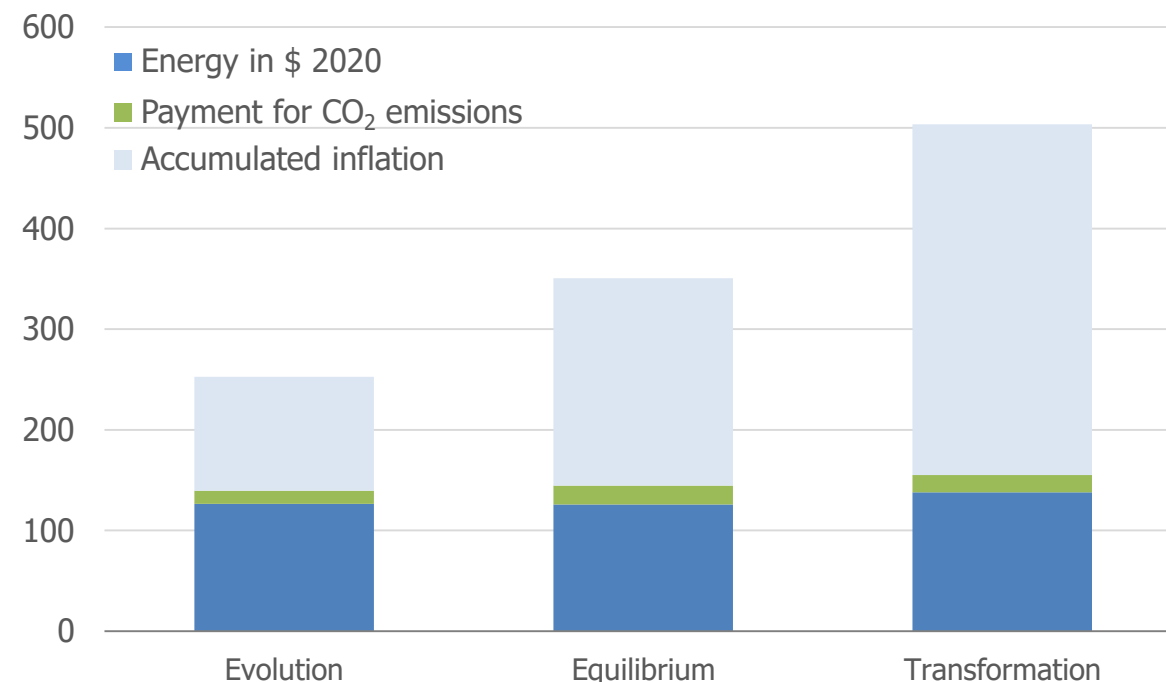
Inflation may reduce the accessibility of energy for consumers

World oil prices in 2050 according to scenarios, \$/bbl



- ▶ Oil prices, taking into account the carbon price, will vary greatly depending on the scenario
- ▶ Setting a carbon price will contribute to the growth in the oil price for the final consumer
- ▶ In the "Transformation" scenario, high carbon prices and inflation will lead to an increase in global oil prices to \$380/bbl

The average cost of energy for consumers in 2050 according to scenarios (projection for the USA), \$/boe



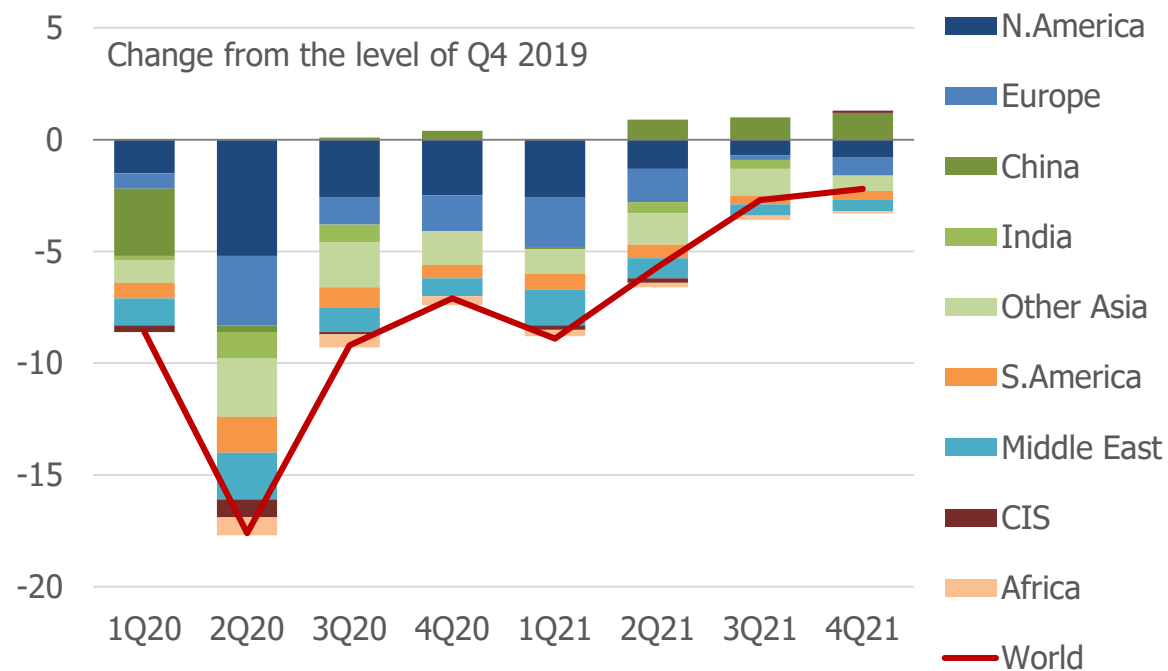
- ▶ The cost of energy for end users in constant prices will be comparable in all scenarios, since the increase in the cost of fossil fuels will be offset by a decrease in their share in the energy mix
- ▶ As a result of elevated inflation, the cost of energy for end users in the "Transformation" scenario by 2050 will be considerably higher than in the "Evolution" scenario



HYDROCARBON MARKET

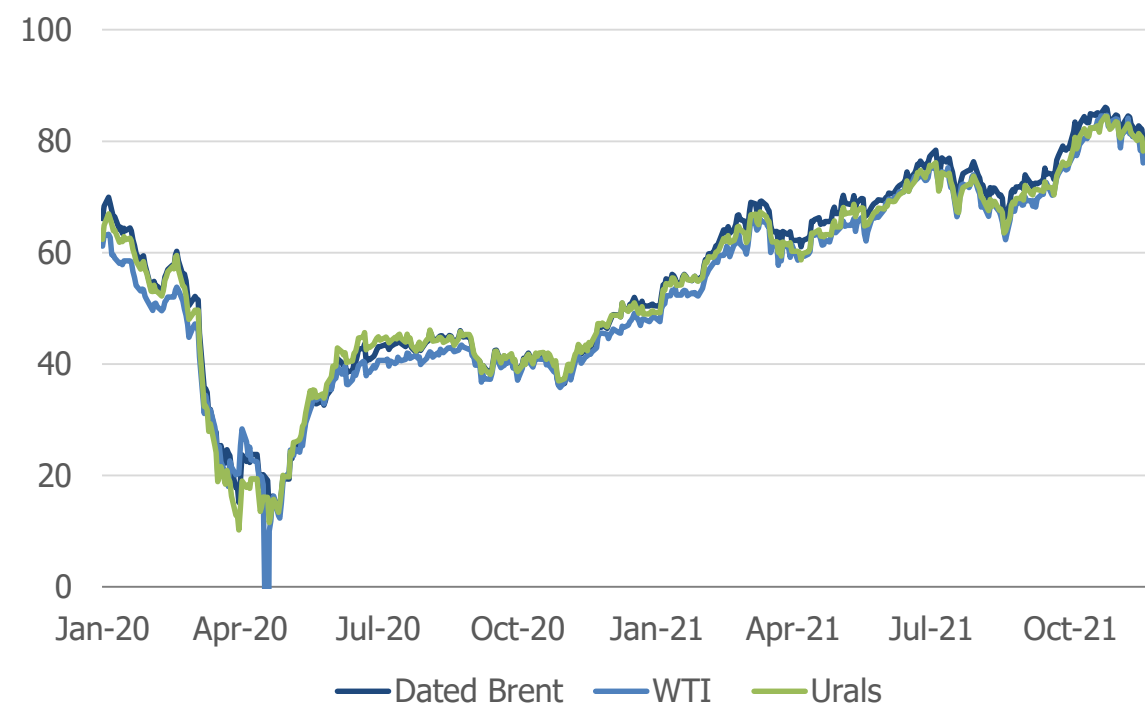
Oil demand is gradually recovering after a record fall in 2020

Actual dynamics of oil demand by region, mb/d



- ▶ As a result of COVID-19 restrictions, the demand for liquid hydrocarbons decreased by a record 18 mb/d in the 2-nd quarter of 2020
- ▶ As restrictions are lifted, demand is gradually recovering
- ▶ The oil demand in China has already exceeded the level of 2020

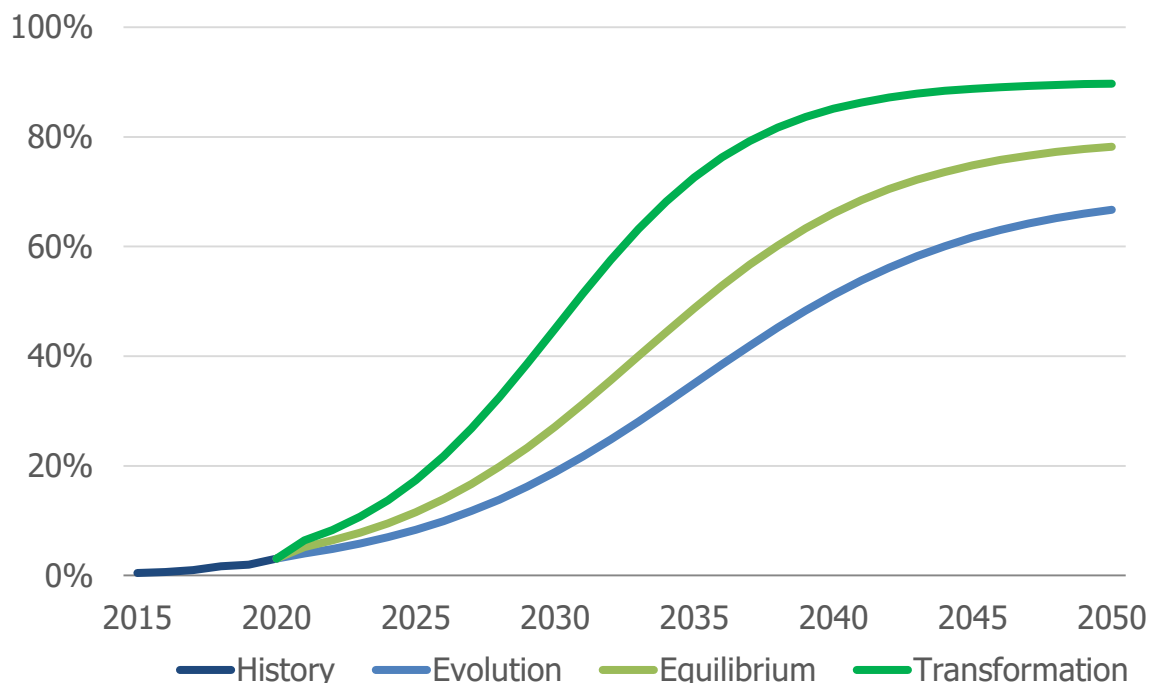
Actual oil price dynamics, \$/bbl



- ▶ Oil prices in 2021 recovered after a sharp drop in spring 2020
- ▶ The coordinated actions of the OPEC+ Agreement participants allowed to stabilize oil prices at levels high enough to maintain investment activity in the oil industry

Structural changes in the car fleet will determine the long-term dynamics of oil demand

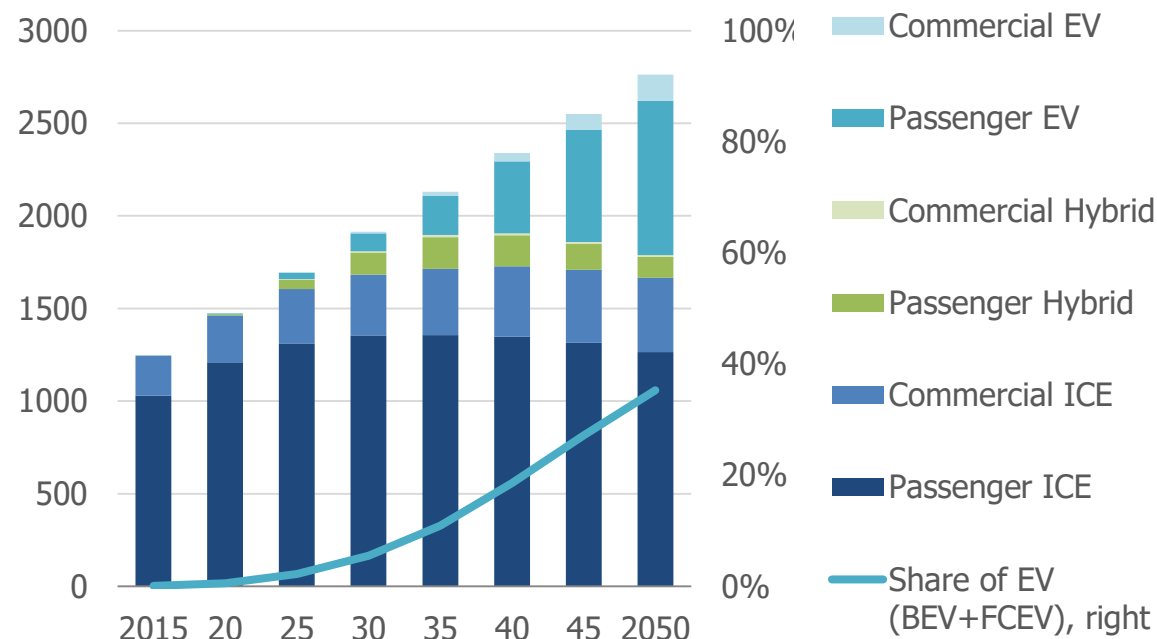
The share of electric vehicles (BEV+FCEV*) in the structure of global passenger car sales, %



* BEV – Battery electric vehicle, FCEV – Fuel cell electric vehicle

- ▶ Sales of electric vehicles will grow due to the decarbonization policy of the transport sector in Europe, USA and China
- ▶ The dynamics of EV sales will vary significantly by region
- ▶ Electrification of commercial transport will be slower than passenger transport due to technical and economic constraints

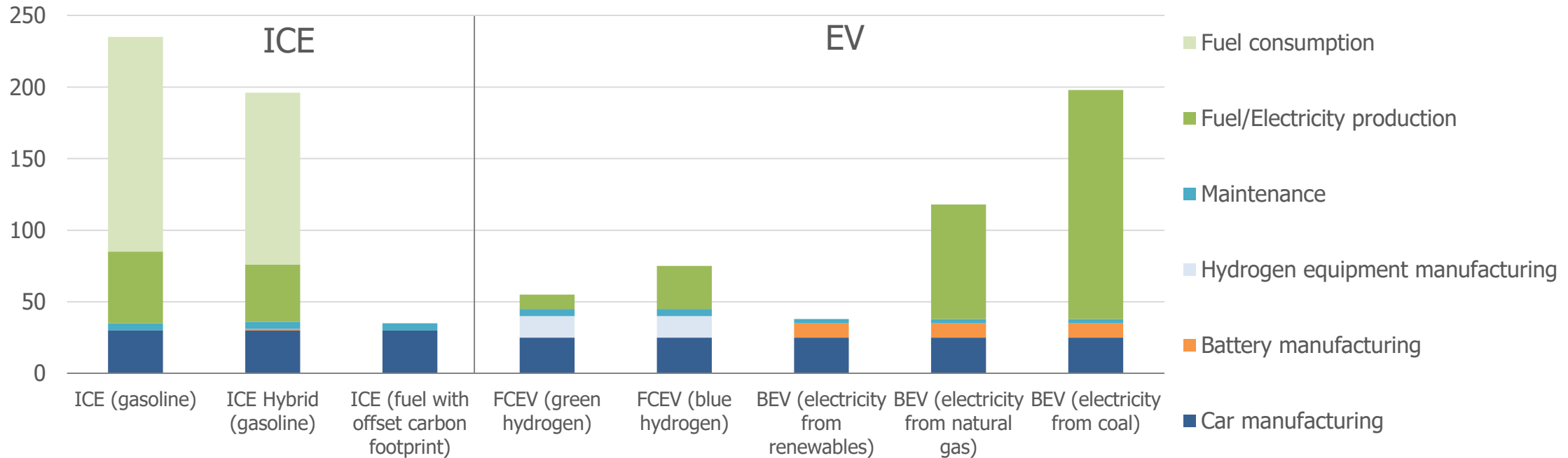
Global car fleet by engine types in the “Evolution” scenario, mln units



- ▶ High demand for cars in developing countries contributes to the growth of the global fleet
- ▶ The fleet of cars with internal combustion engines as of 2020 totals 1,5 billion cars. Replacing such a number of cars with electric vehicles will take a long time
- ▶ In the “Evolution” scenario, the share of electric vehicles in the total car fleet will increase from the current 1% to 35% by 2050

The carbon footprint of a car with an internal combustion engine can be comparable to those of an electric car under certain conditions

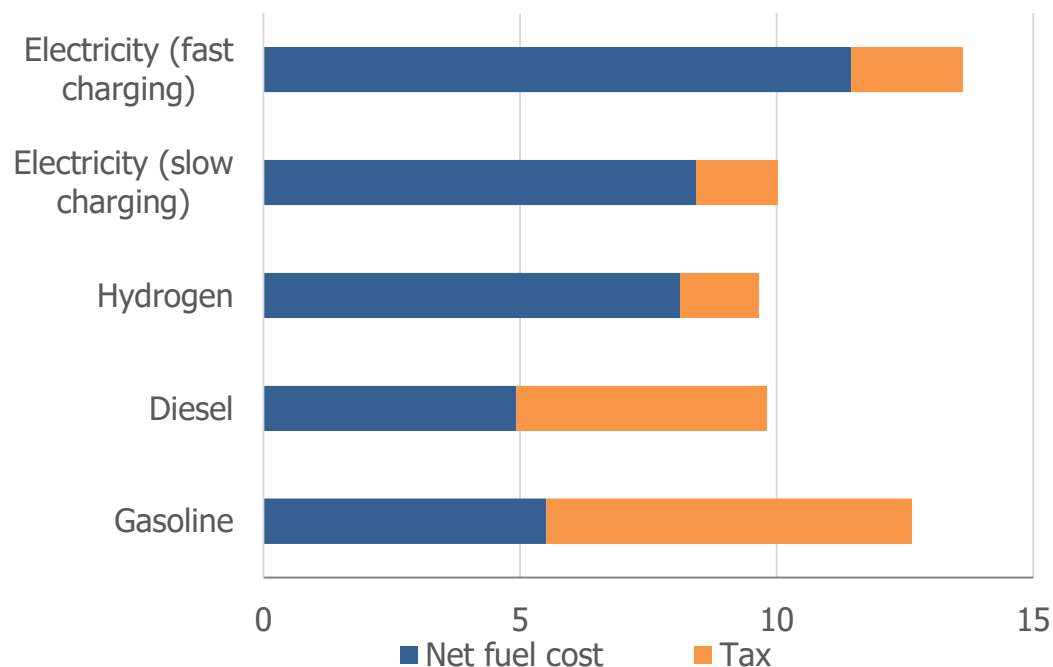
CO₂ emissions over the entire life cycle (well-to-wheel) for an average passenger car, g CO₂/km



- ▶ CO₂ emissions from the manufacturing of ICE cars are lower than from electric vehicles production, while a car with an ICE produces the major amount of emissions when burning fuel
- ▶ The carbon footprint of an electric vehicles strongly depends on the source of electricity it uses: emissions from an electric vehicle when using electricity generated from coal are comparable to emissions from a hybrid car with an ICE
- ▶ The use of fuel with an extinguished carbon footprint (i.e. carbon certificates confirming the offset of the carbon footprint from fuel production and consumption) is one of the possible ways to significantly reduce emissions from cars with ICE

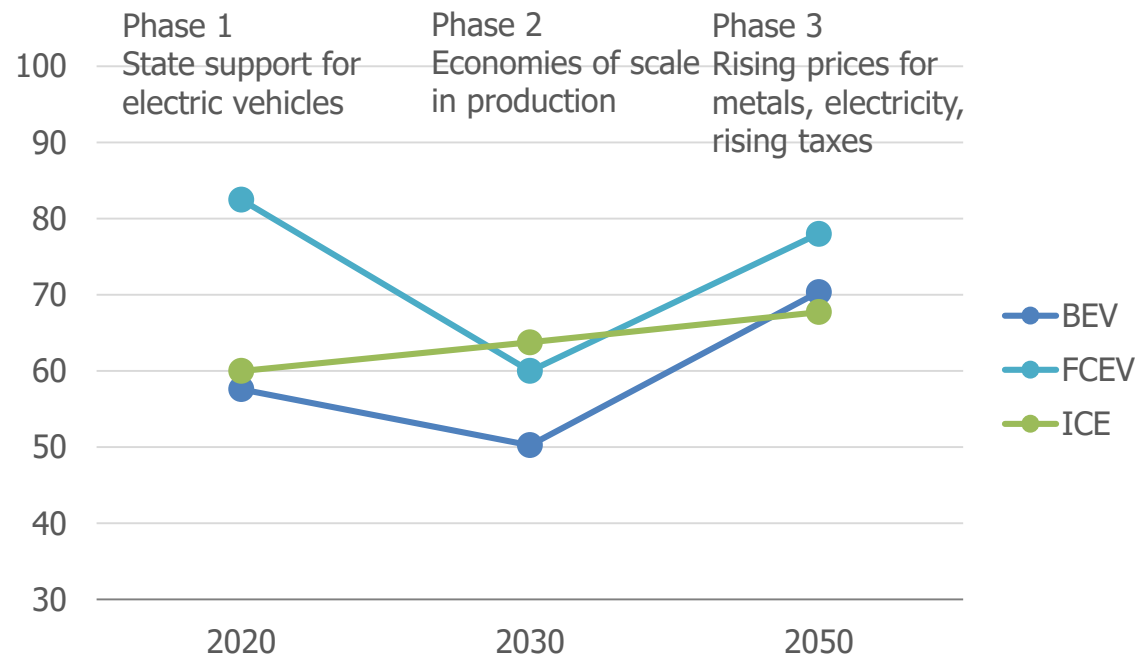
The cost of owning an electric car will gradually increase

The cost of a kilometer of mileage in Western Europe for various types of fuels as of November 2021, \$/100 km



- ▶ Taxes account for about 50% of the retail price of traditional motor fuels in Europe, which reduces the competitiveness of fossil fuels in transport
- ▶ In certain market conditions (such as in the second half of 2021), electricity may cost more to consumers than traditional fuels, especially when using fast charging network

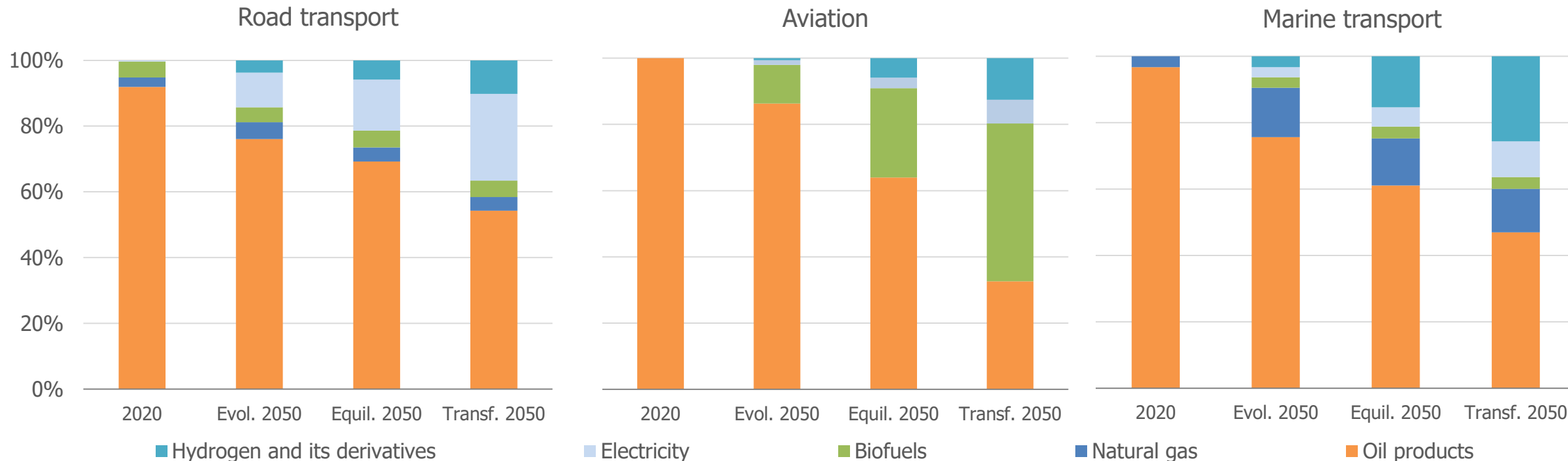
Forecast of the total cost of ownership of a medium-sized passenger car in Europe, \$/100 km



- ▶ In the medium term, the cost of ownership of an electric car will decrease due to scaling up production
- ▶ In the longer term, the cost of owning an electric car will increase due to rising prices for metals, electricity and the need to recycle batteries
- ▶ The increase in electricity taxes may also be one of the reasons for the increase in the cost of owning an electric car

The fuel structure of the transport sector will become more diverse

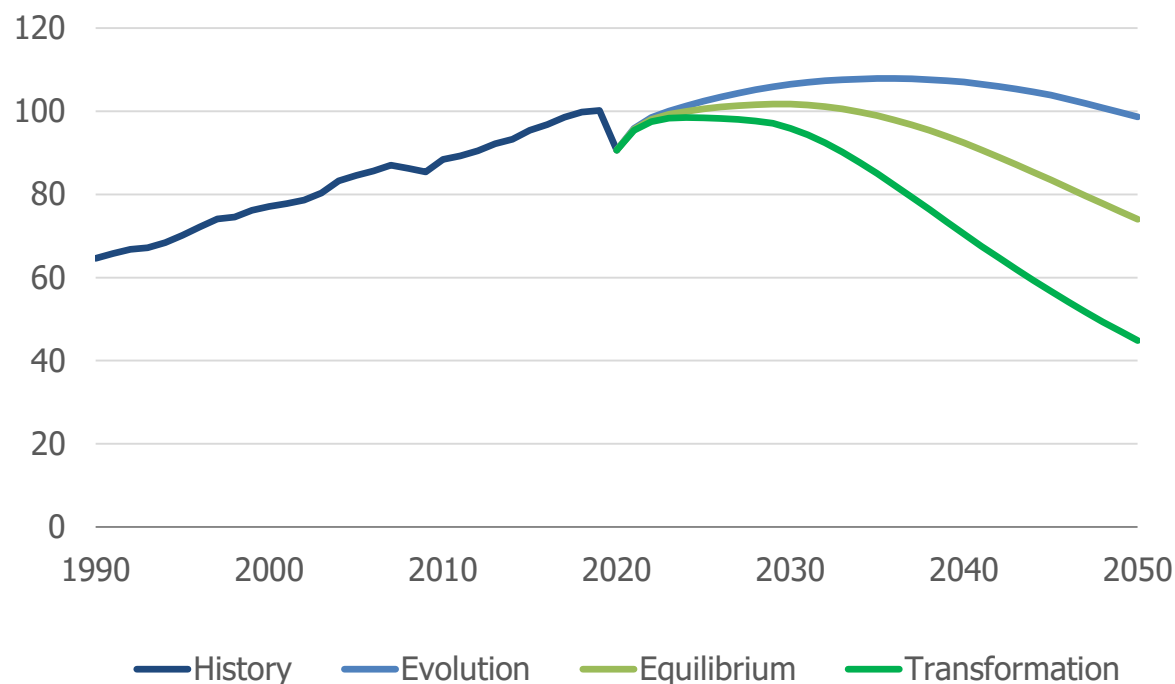
Fuel structure of the transport sector, %



- ▶ The fuel structure of the transport sector will change due to an increase of low-carbon fuels share
- ▶ In the segment of road transport, the most noticeable increase will be in electricity and hydrogen consumption
- ▶ Aviation is expected to increase the consumption of modern biofuels (SAF)
- ▶ Stricter environmental requirements in international shipping will encourage shipowners to switch to the use of natural gas, hydrogen and its derivatives

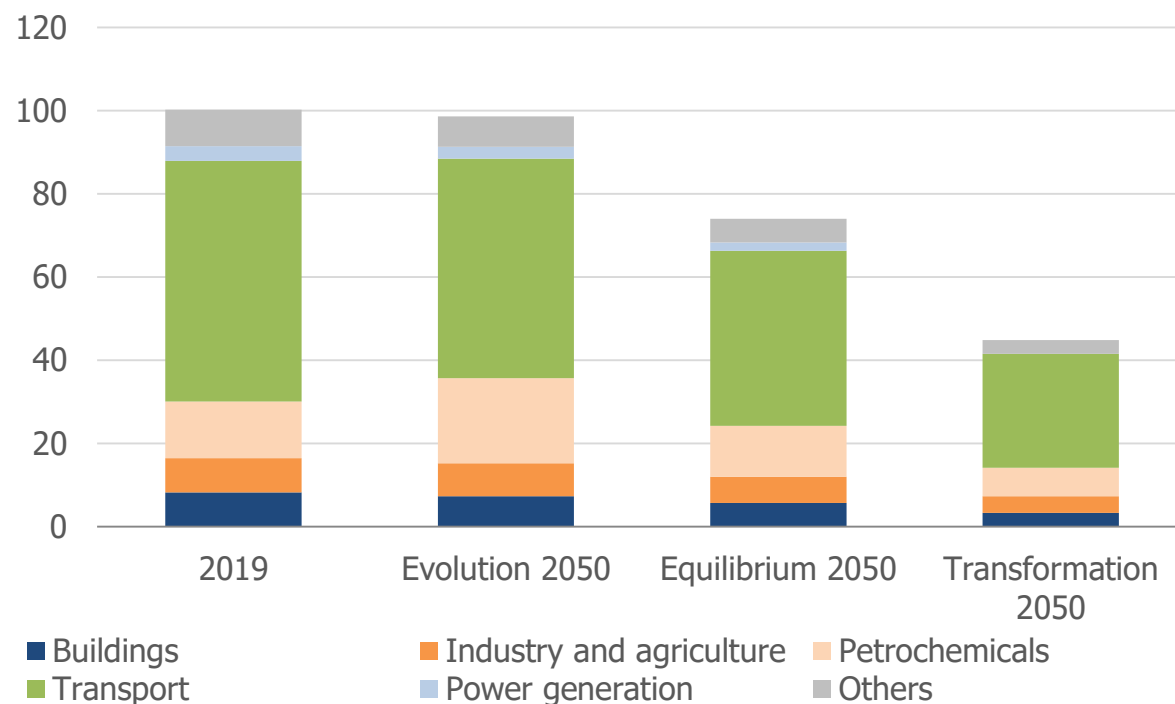
Consumption of liquid hydrocarbons will remain stable at least until 2030

Forecasts of global demand for liquid hydrocarbons, mb/d



- ▶ In the next few years, demand for liquid hydrocarbons is expected to recover after the shock of 2020
- ▶ In the "Evolution" scenario, the growth of liquid hydrocarbons consumption will continue until 2035
- ▶ Structural changes in the transport sector will begin to affect the demand for liquid hydrocarbons after 2030

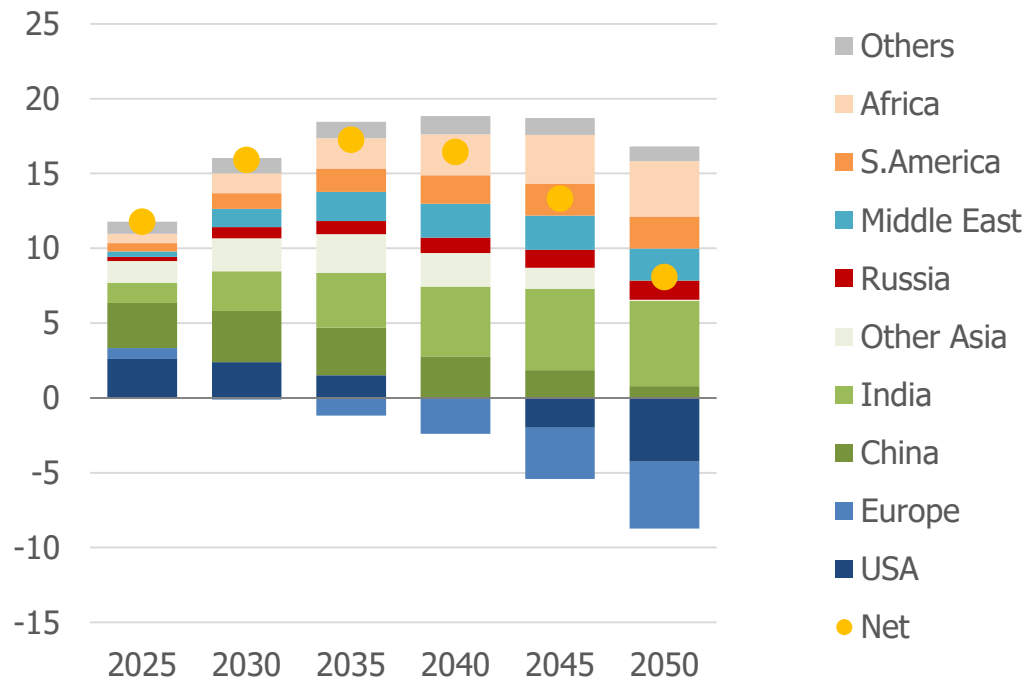
Consumption of liquid hydrocarbons by sector, mb/d



- ▶ The transport sector will continue to dominate in the structure of demand for liquid hydrocarbons
- ▶ In the "Evolution" scenario, the increase in the consumption of petroleum products by aviation and marine transport will partly compensate the reduction in the consumption of motor fuels in road transport
- ▶ The growth in the consumption of hydrocarbons in the petrochemical sector will support the demand for oil in the medium term

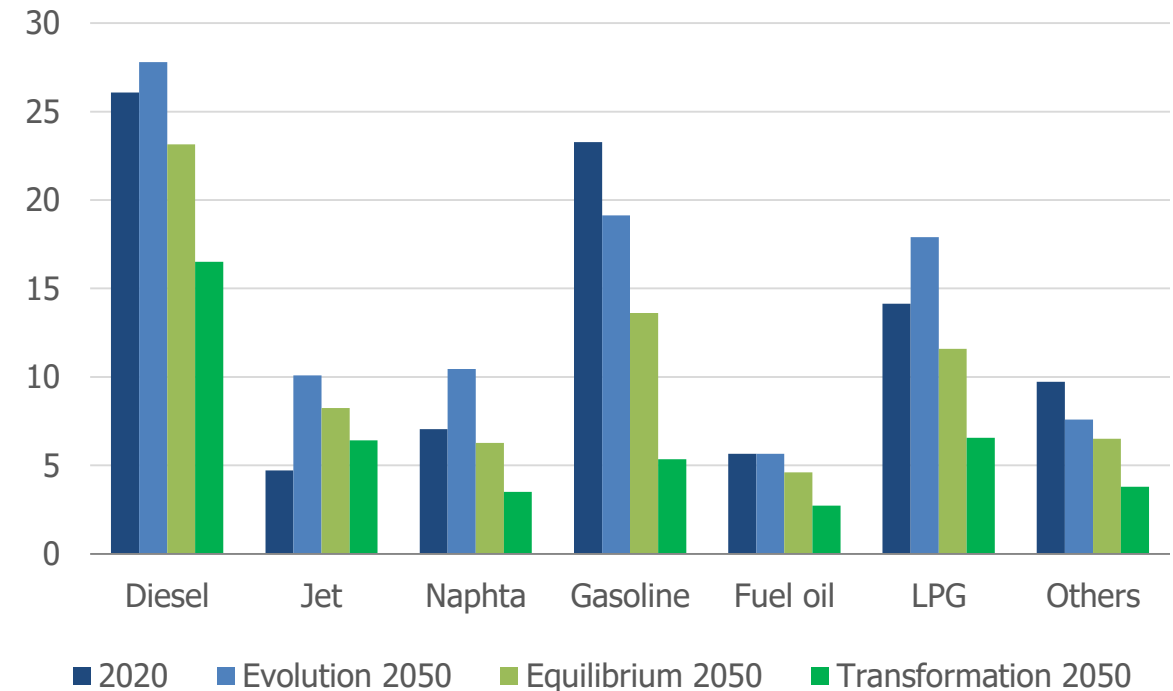
The main increase in the consumption of liquid hydrocarbons in the next decade will be provided by the countries of the Asia-Pacific region

Change in consumption of liquid hydrocarbons by region relative to 2020 ("Evolution scenario"), mb/d



- ▶ The dynamics of demand for liquid hydrocarbons will vary significantly in different regions
- ▶ The decline in consumption in Europe and USA will be compensated by growth in other regions
- ▶ The key growth drivers of oil demand in the long term will be India and the countries of the African continent

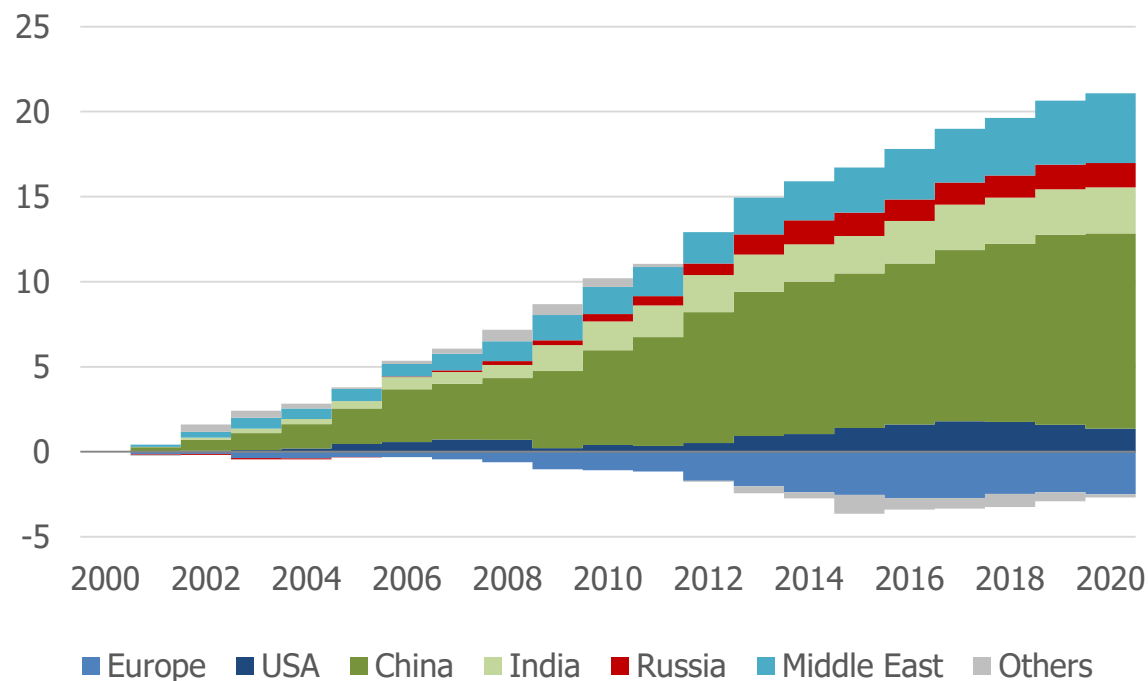
Consumption of liquid hydrocarbons by fuel types, mb/d



- ▶ The fuel structure of demand for liquid hydrocarbons will gradually change
- ▶ Gasoline consumption will decrease in all considered scenarios
- ▶ Petrochemical feedstock, jet fuel, bitumen and lubricants will demonstrate a better demand dynamics than traditional motor fuels

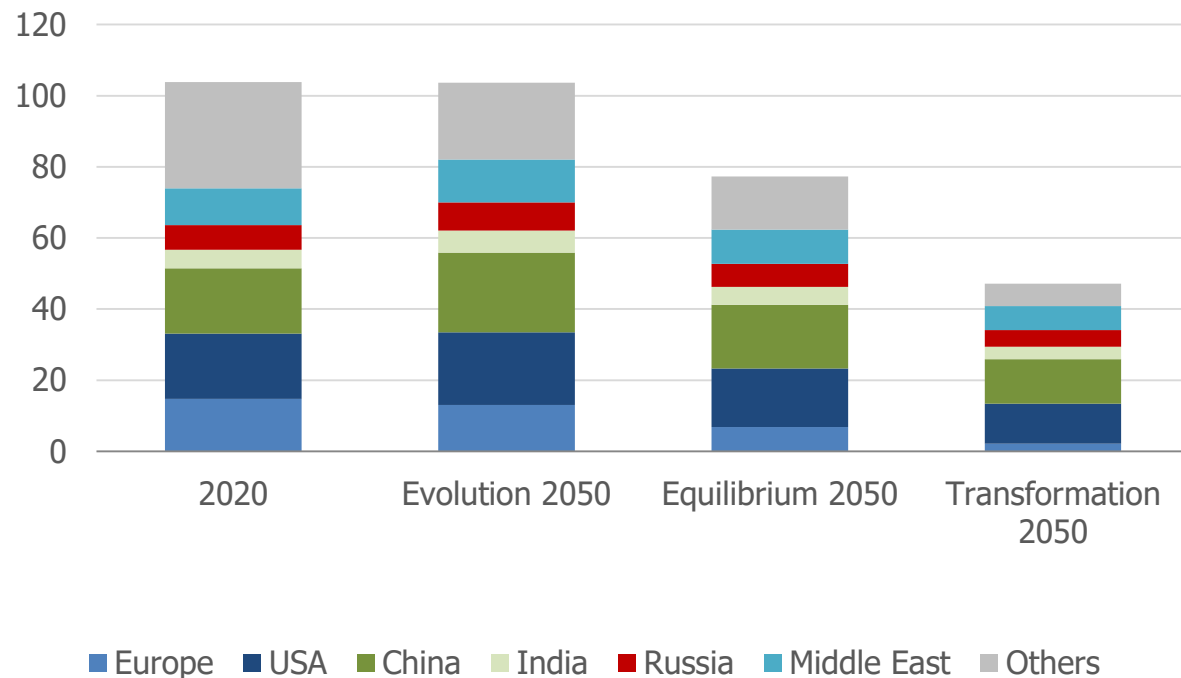
The oil refining industry will adapt to the changing demand for petroleum products

Cumulative change in refining capacity by region, mb/d



- ▶ In the last decade, new oil refining capacities were mainly constructed in China and the Middle East
- ▶ Increased competition in petroleum products market as a result of new modern refineries entering the market leads to the closure of inefficient capacities, many of which are located in European countries

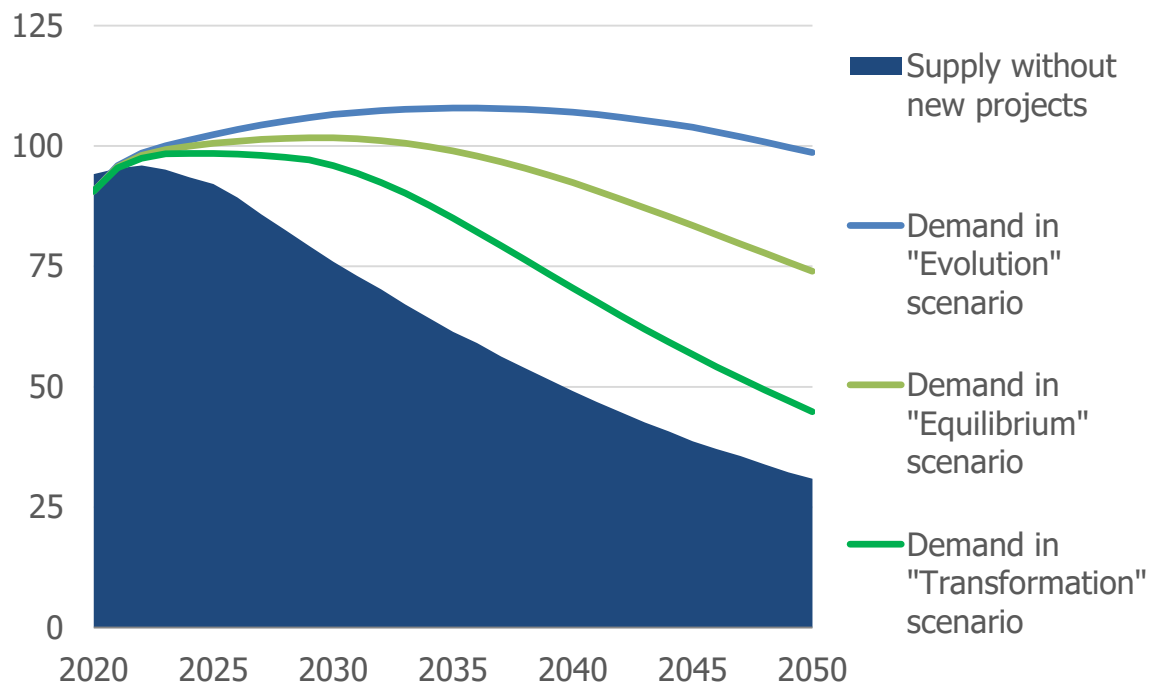
Forecast of refining capacity by region, mb/d



- ▶ The refining capacities will change in proportion to the demand for petroleum products
- ▶ In countries with growing consumption of petroleum products, such as China and India, the construction of new refining capacities will continue
- ▶ The largest reduction in refining capacity is expected in European countries, where petroleum products consumption growth will be low or negative

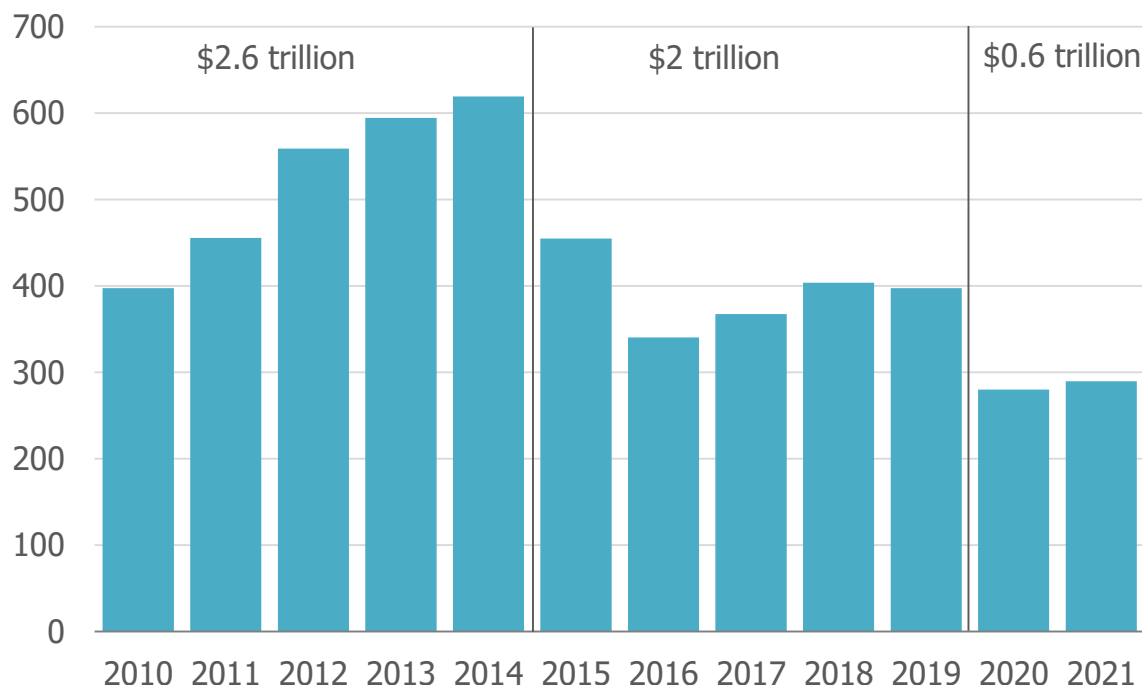
The need for investment in oil production will persist even in the most pessimistic demand scenario

Demand and supply of liquid hydrocarbons (without new projects), mb/d



- ▶ A significant number of oil fields are in the late stages of development and have a falling production profile
- ▶ The natural decline in production at such fields creates the need for new projects to meet demand
- ▶ In the absence of investments, the supply of liquid hydrocarbons will decrease annually at a rate of 4-5%

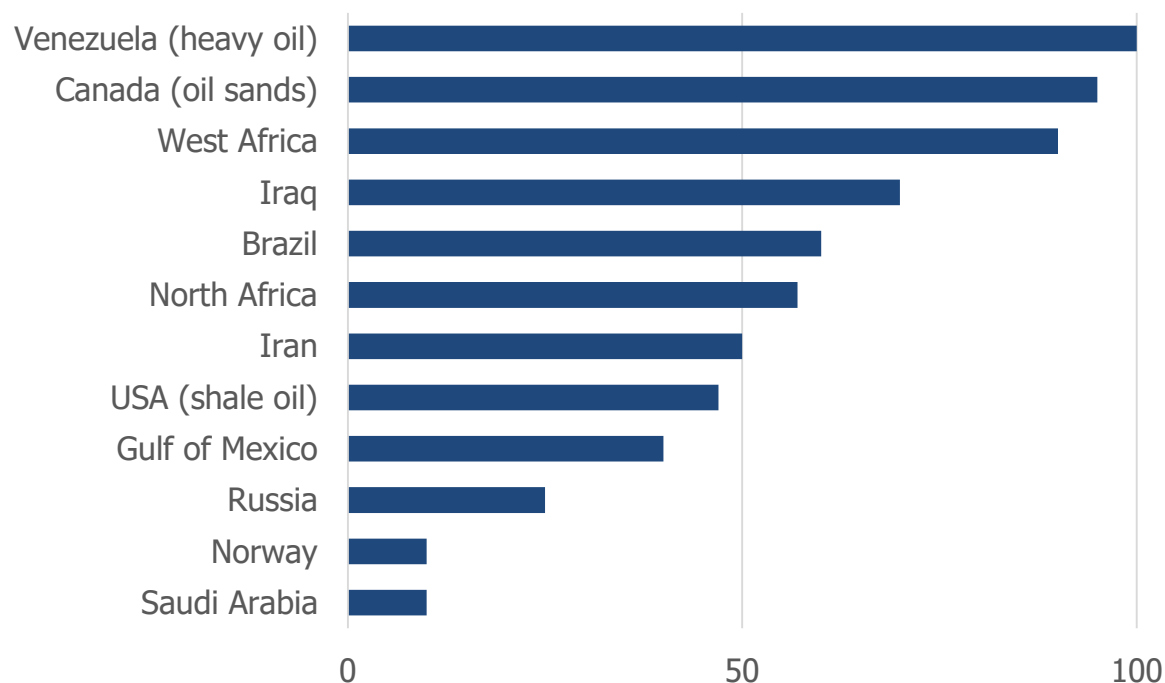
Actual investments in oil exploration and production, \$ bln



- ▶ There has been a steady downward trend in investment in oil exploration and production since 2014
- ▶ In part, the reduction in investment is due to the costs optimization for new projects. However, a significant part of the reductions is associated with postponements or abandonments of projects
- ▶ Underinvestment can lead to a steady shortage of supply in the market and an increase in price volatility

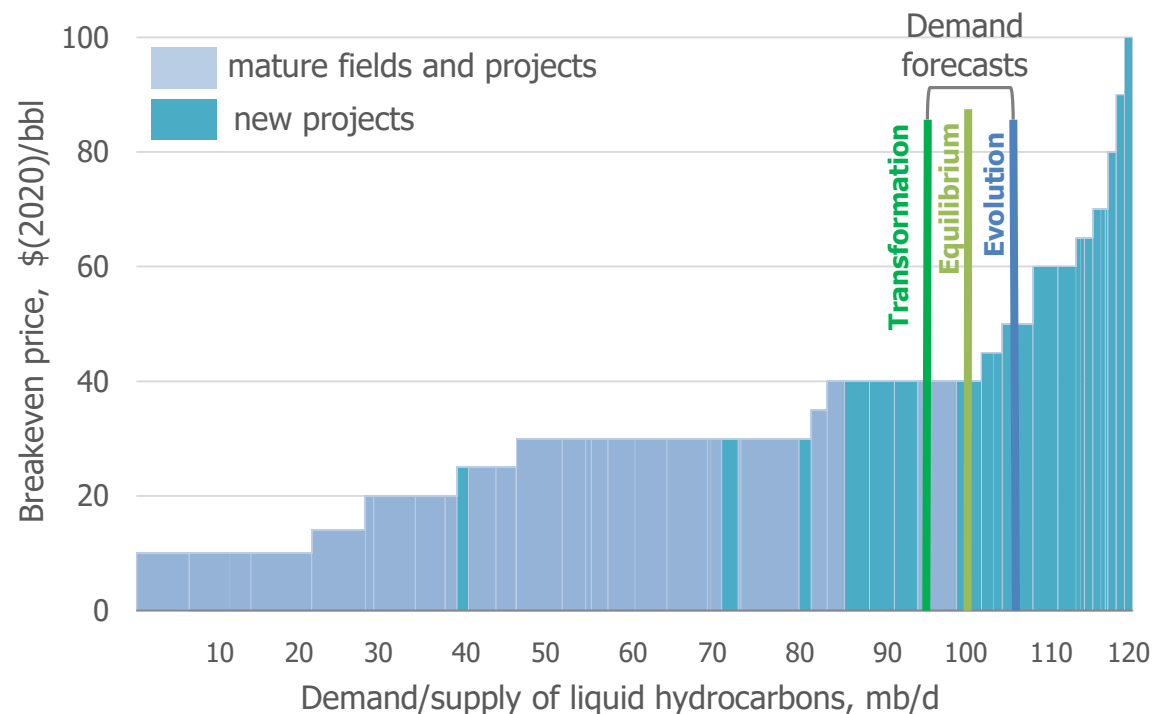
The market will require hydrocarbons with low production cost and low carbon footprint

Carbon intensity of oil production by countries and regions, kg CO₂e/boe



- ▶ Strengthening of climate regulation will motivate consumers to purchase oil with low carbon footprint
- ▶ The carbon footprint of oil is affected by many factors, the most significant among which are the density of oil, field water cut, the level of flaring and methane leaks
- ▶ Oil produced in Saudi Arabia, Norway and Russia has the lowest carbon intensity

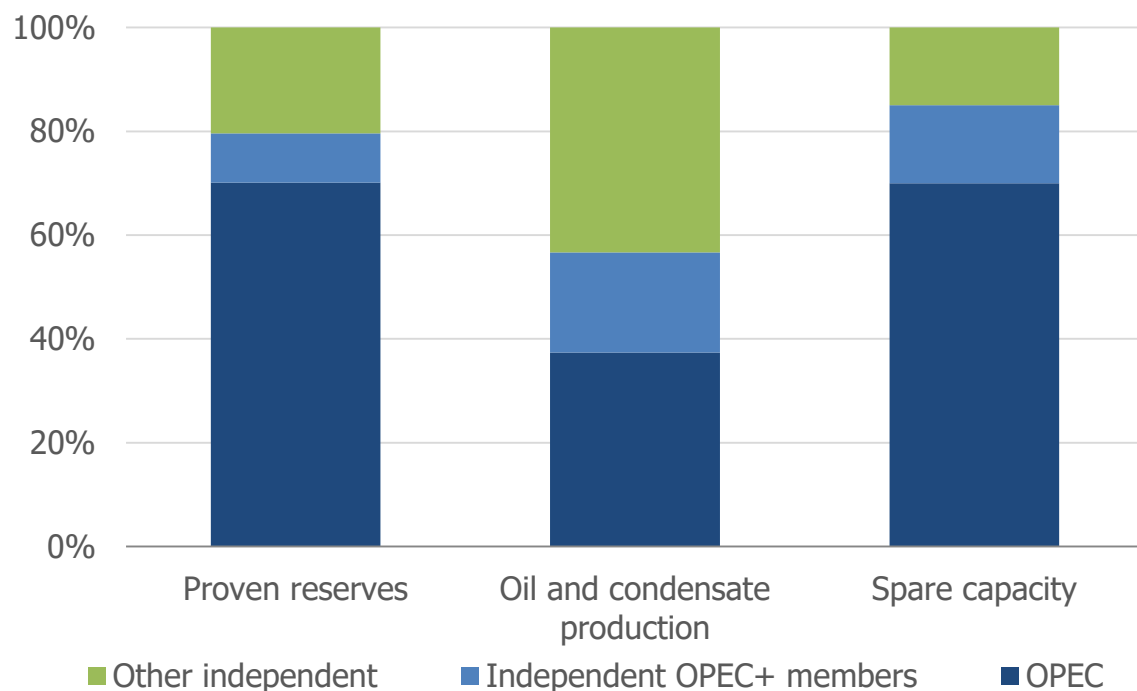
Demand forecasts and supply curve of liquid hydrocarbons for 2030



- ▶ Under conditions of a slowdown in liquid hydrocarbons demand growth, the cost of production will be one of the most important factor for sanctioning new projects
- ▶ A significant part of the reserves with high breakeven price, including the Arctic shelf, oil sands and heavy oil, may remain undeveloped

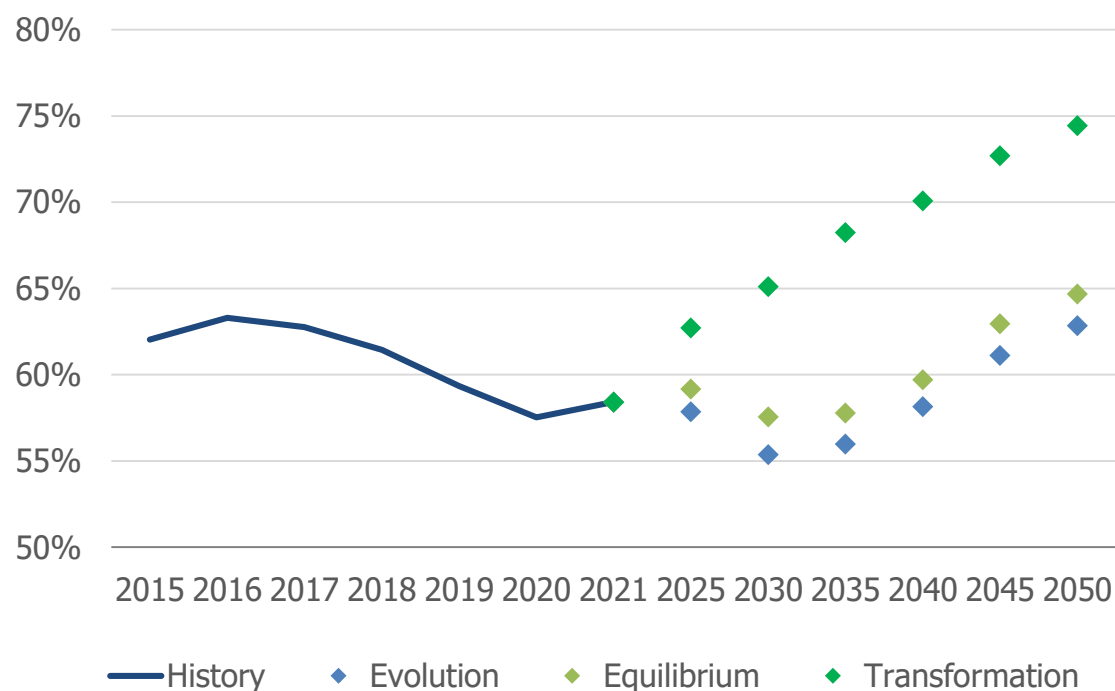
The share of OPEC+ in global oil production will increase

OPEC+ position on the global oil market in 2019



- ▶ OPEC remains the key regulatory mechanism in the oil market, which continues to demonstrate its effectiveness. Thanks to the OPEC+ agreement, it was possible to mitigate the shock of an unprecedented drop in oil demand in 2020
- ▶ The excess of spare production capacity will contribute to further cooperation of oil-producing countries in the OPEC+ format

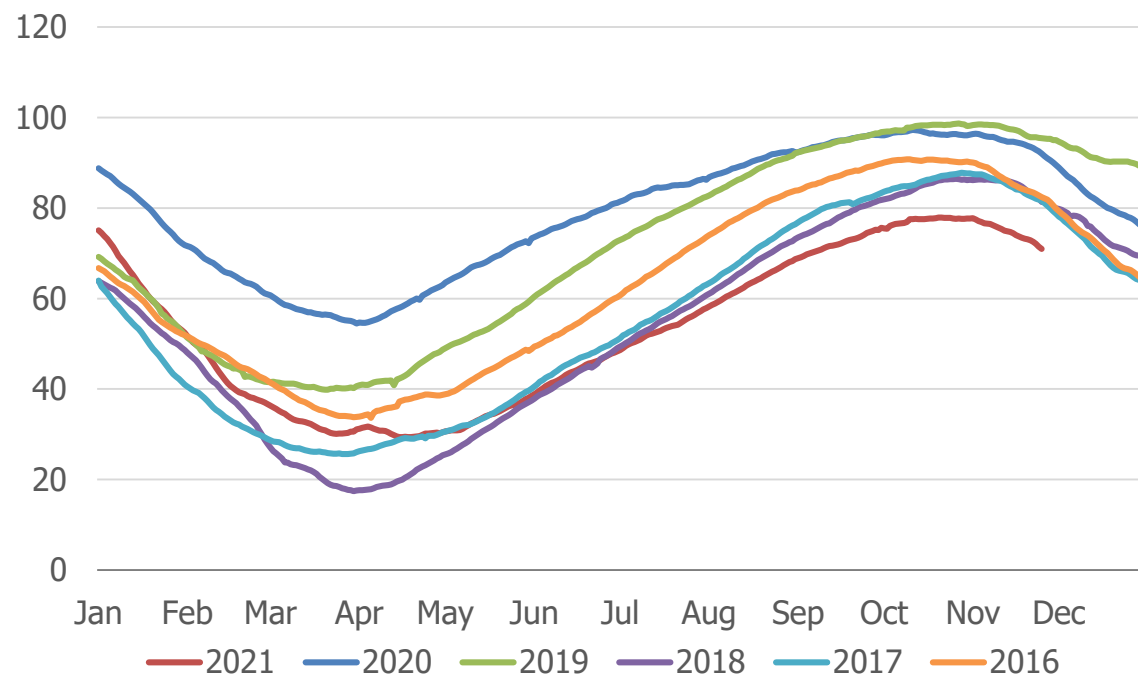
OPEC+ share in global oil production, %



- ▶ The share of OPEC+ agreement participants in global oil production will increase in the long term
- ▶ New projects in the countries participating in the OPEC+ agreement are characterized by low breakeven prices
- ▶ The carbon footprint of oil production in these OPEC+ member countries is estimated to be low or moderate

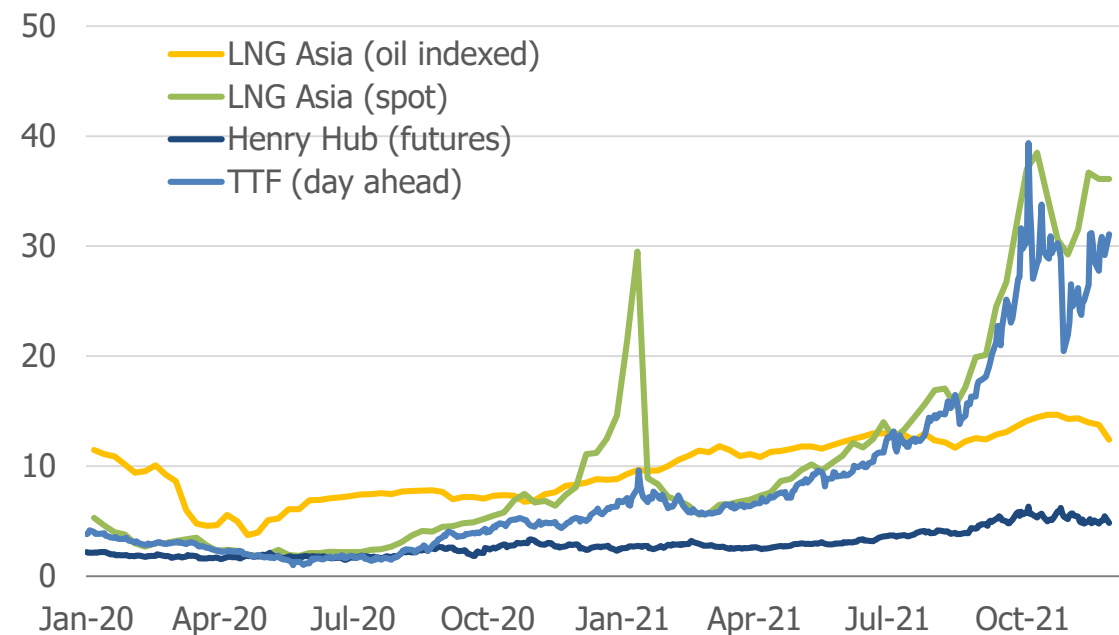
The surplus in the gas market in 2020 changed to a deficit in 2021

Dynamics of stocks in European underground gas storage facilities, bcm



- ▶ In 2021, natural gas stocks in Europe's underground storage facilities have fallen to multi-year lows
- ▶ The low level of gas stocks showing the ongoing supply and demand imbalance on the eve of the winter season caused gas prices to rise to historically record levels

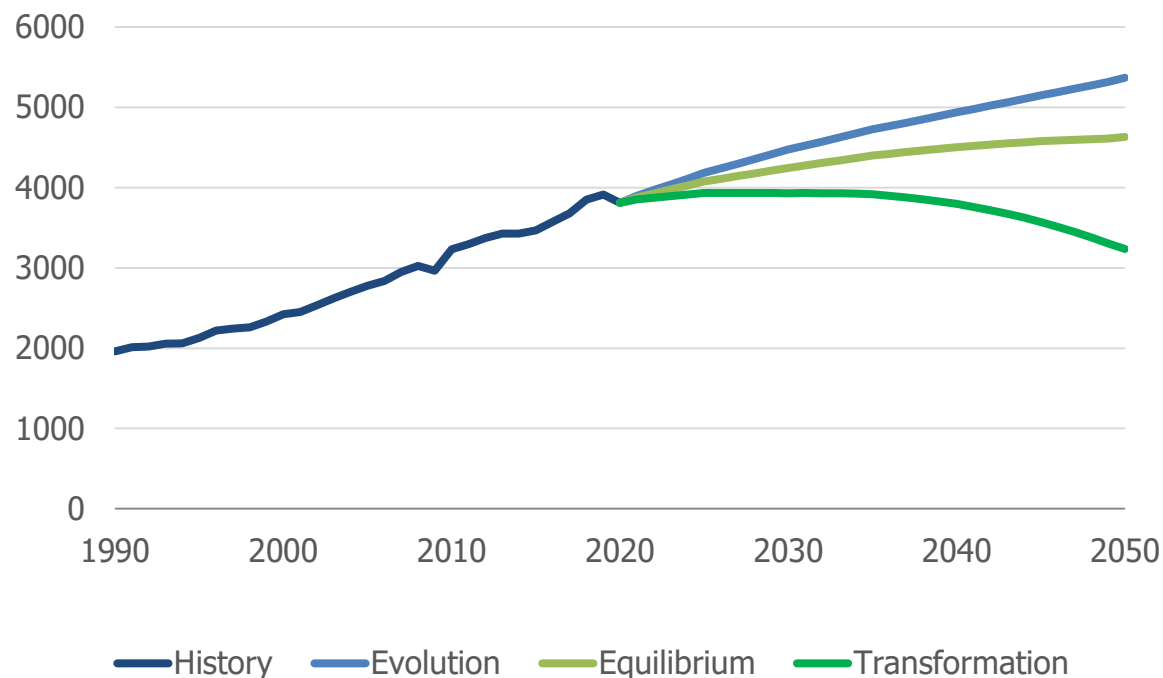
Historical dynamics of gas prices, \$/mmbtu



- ▶ Unfavorable weather conditions, the recovery of economic activity, a decline in domestic production and a decrease in gas imports are factors contributing to support European spot gas prices at high levels
- ▶ A sharp increase in spot gas prices is also observed in Asia, where a rapid economic recovery is happening after the removing of quarantine restrictions

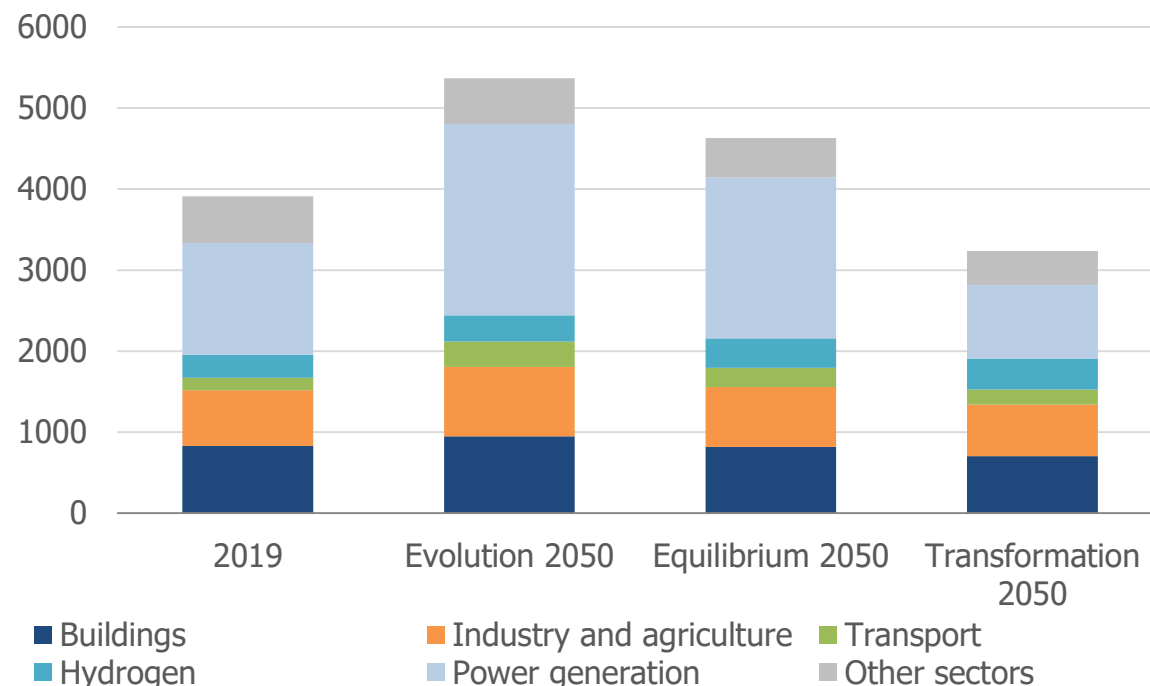
The demand for gas will grow faster than the demand for liquid hydrocarbons

Forecasts of global gas demand, bcm



- ▶ The demand for natural gas in the medium term will demonstrate higher growth rates than the demand for liquid hydrocarbons
- ▶ The carbon intensity of natural gas is significantly lower than that of oil and coal, which will stimulate gas consumption in industrial countries
- ▶ In the "Evolution" scenario, gas demand will show growth until 2050

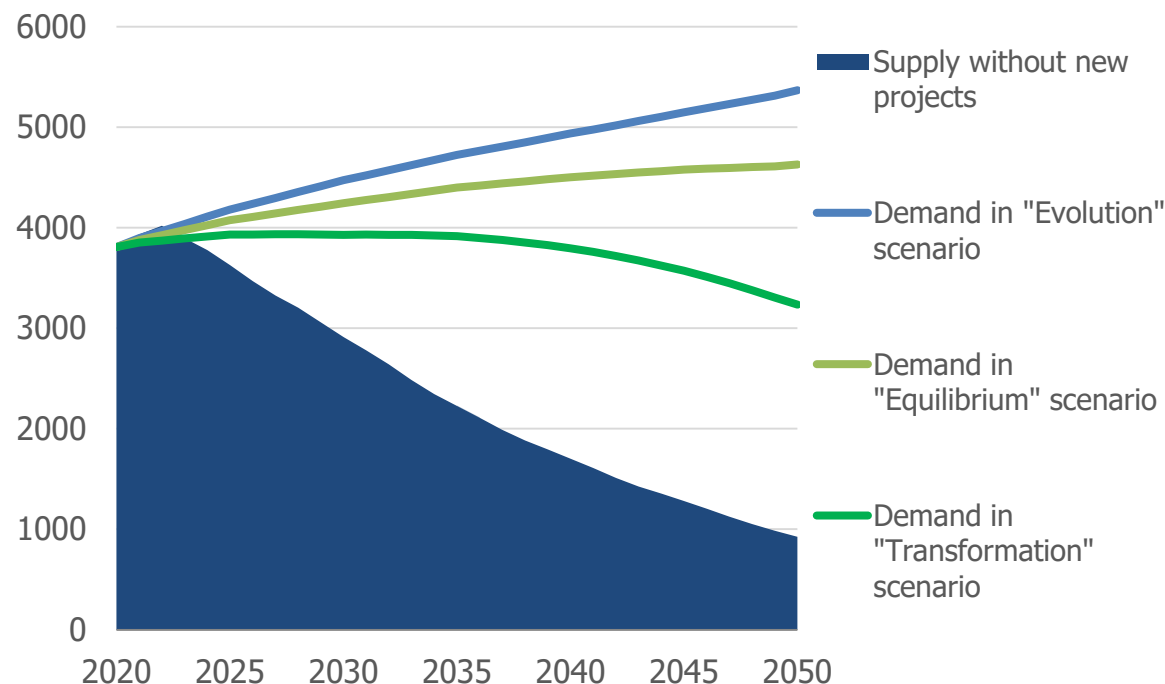
Gas demand by sector, bcm



- ▶ The main growth in natural gas consumption is expected from the power generation sector
- ▶ Electrification of transport will increase the need for new generating capacities, including those fueled by gas
- ▶ Gas generation makes possible to ensure the stability of energy systems with a significant share of generation from RES

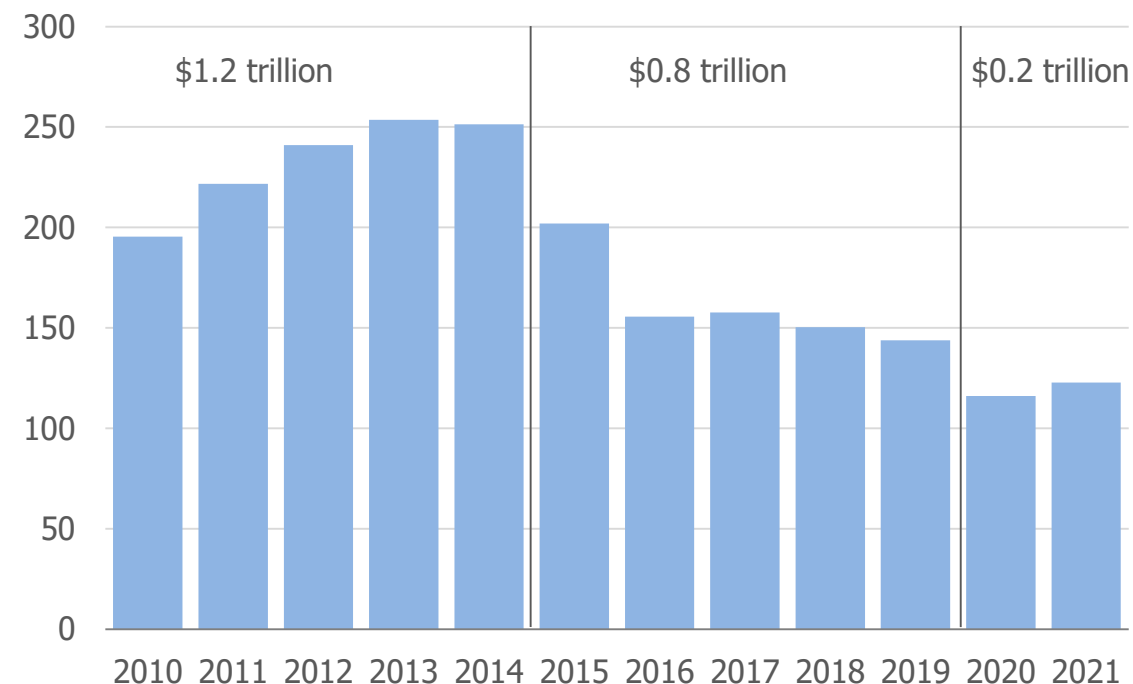
The need for investment in new gas projects will remain at high level

Production at mature fields and gas demand (without new projects), bcm

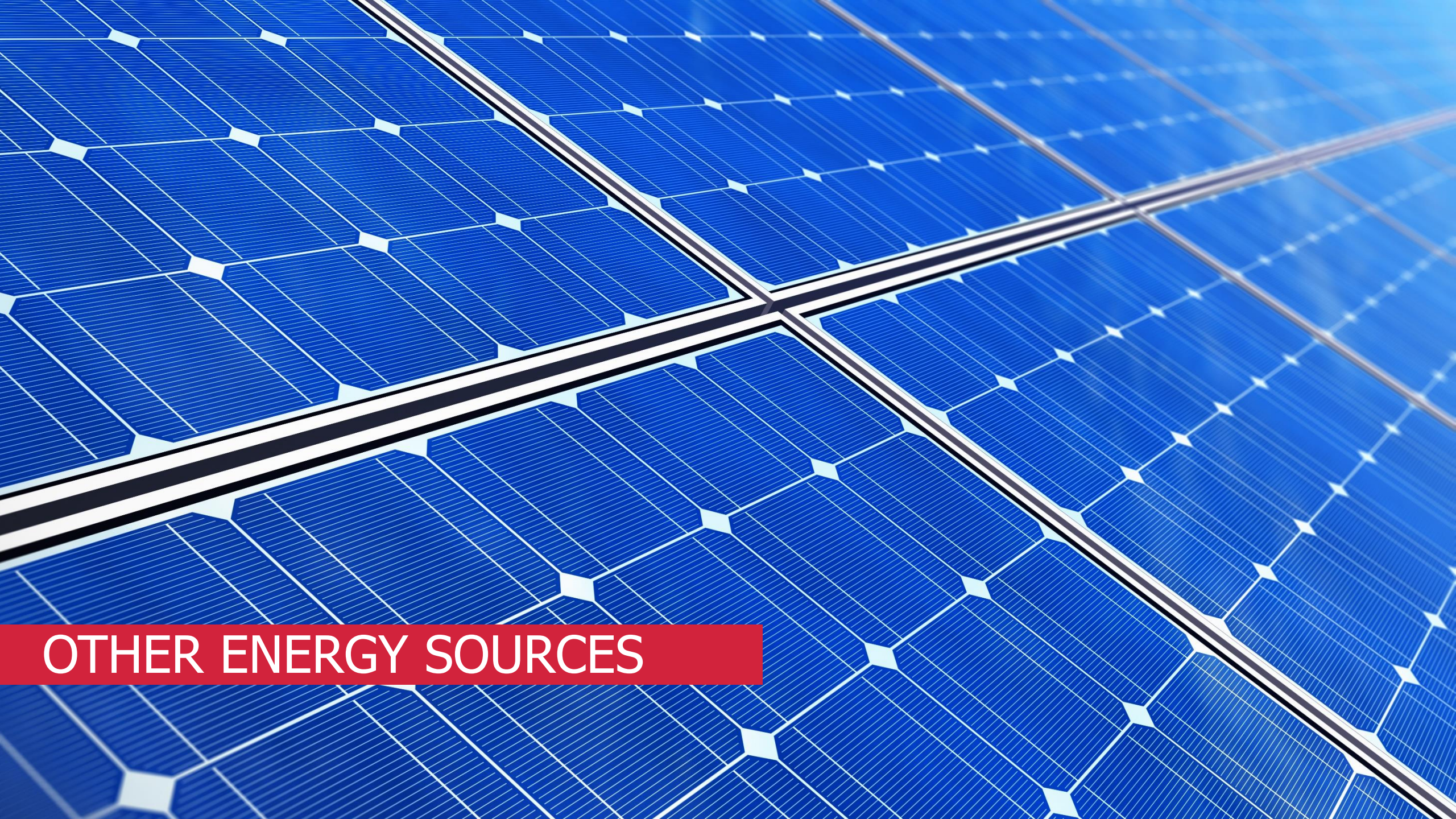


- ▶ The decline in gas production at existing fields causes the need for additional development of existing gas reserves, as well as exploration of new ones
- ▶ The need for new gas production projects by 2050 is estimated in the range from 2.3 to 4.4 bcm

Actual investments in gas projects, \$ bln



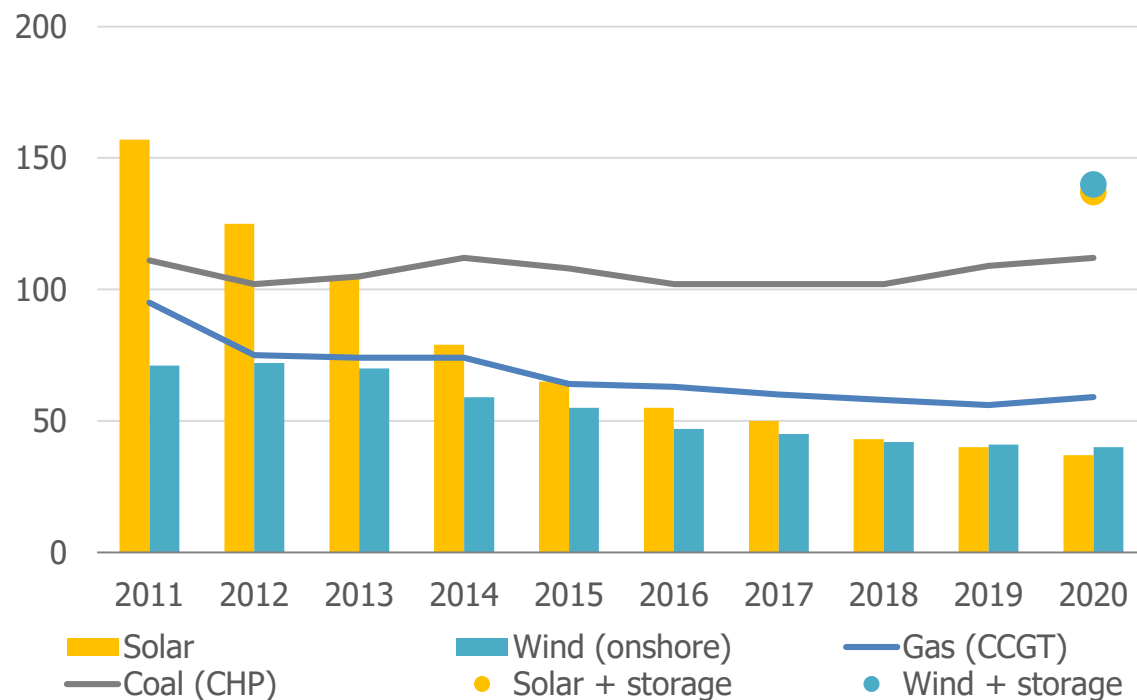
- ▶ The surplus in the gas market as a result of the rapid growth in shale gas production in the United States caused a decrease in investments in exploration and development of gas reserves
- ▶ The growing demand for gas will likely lead to an increase of investment in the gas industry in the coming years



OTHER ENERGY SOURCES

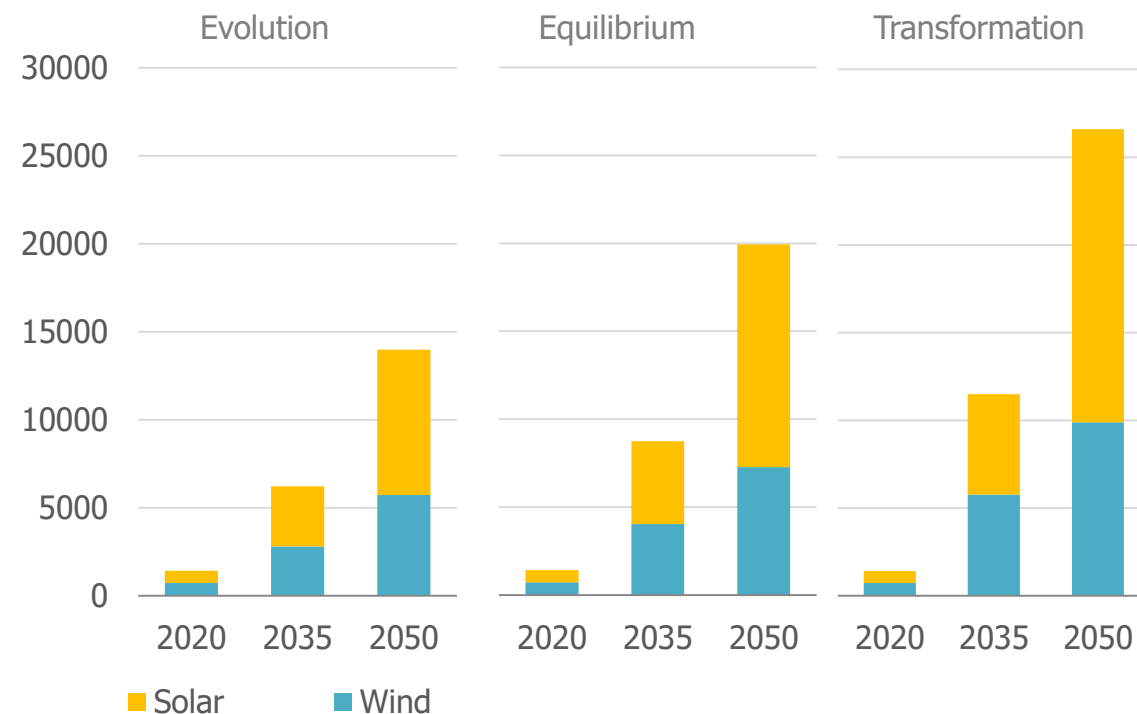
Energy consumption from renewable energy sources will grow rapidly

Levelized cost of energy (LCOE), \$/MWh



- ▶ The levelized cost of solar and wind energy in 2020 was lower than the same indicator for coal and gas generation
- ▶ The cost of industrial batteries is decreasing, but their use together with modern renewable energy sources is still less efficient than the production of electricity from fossil fuels

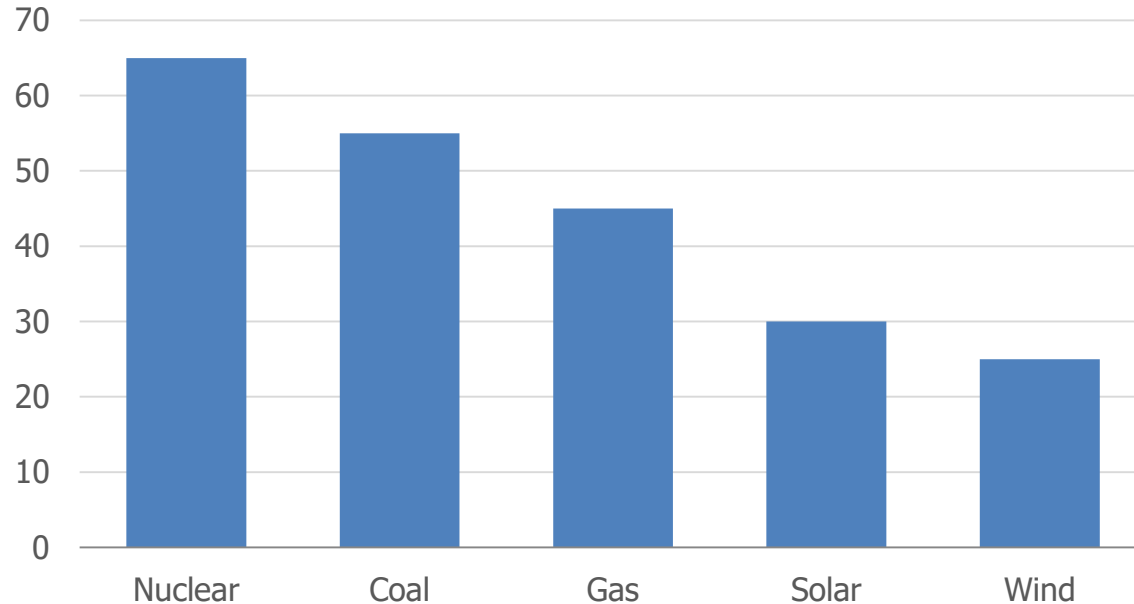
Installed capacity of modern RES, GW



- ▶ The climate policy of the leading industrial countries will stimulate the construction of solar and wind generation
- ▶ The high cost of energy storage systems can act as a deterrent, limiting the possibilities of integrating modern RES into energy systems
- ▶ Territorial restrictions may become an obstacle to the development of RES in certain countries

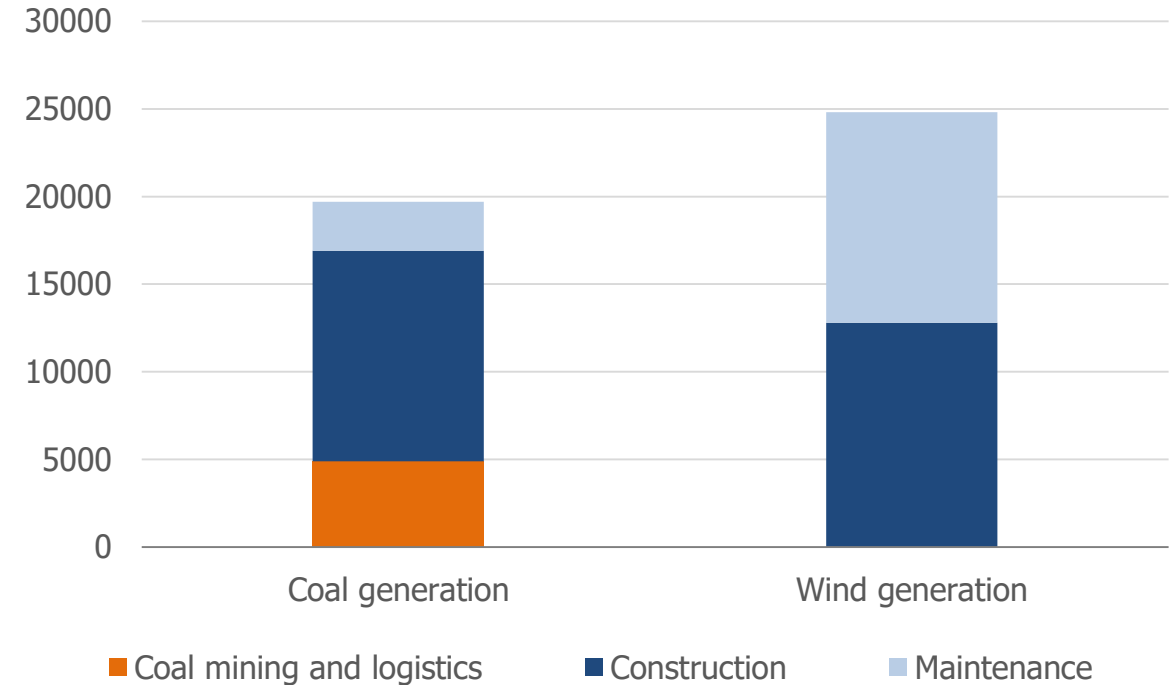
Relatively short service life of modern RES will contribute to the growth of energy sector decarbonization costs

Average service life of power plants by type, years



- ▶ Modern wind and solar power plants have a shorter service life than traditional power plants using fossil fuels or nuclear power plants
- ▶ The need for more frequent capacity renewal compared to traditional power generation increases the cost of using RES

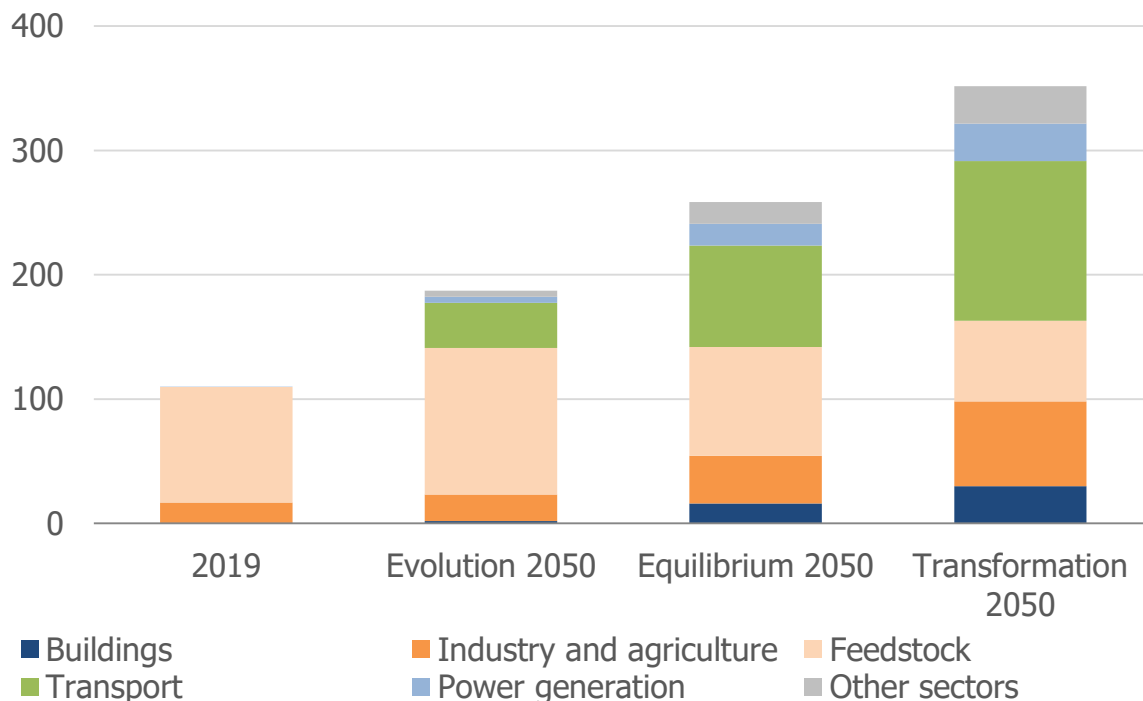
Comparison of staff requirement in coal and wind power, people/100 TWh



- ▶ The transition to low-carbon methods of electricity production will be accompanied by a large-scale flow of labor between sectors of the economy
- ▶ Renewable energy requires more people per unit of energy generation than traditional energy
- ▶ There may be a shortage of labor in energy sector, which may affect the cost of decarbonization

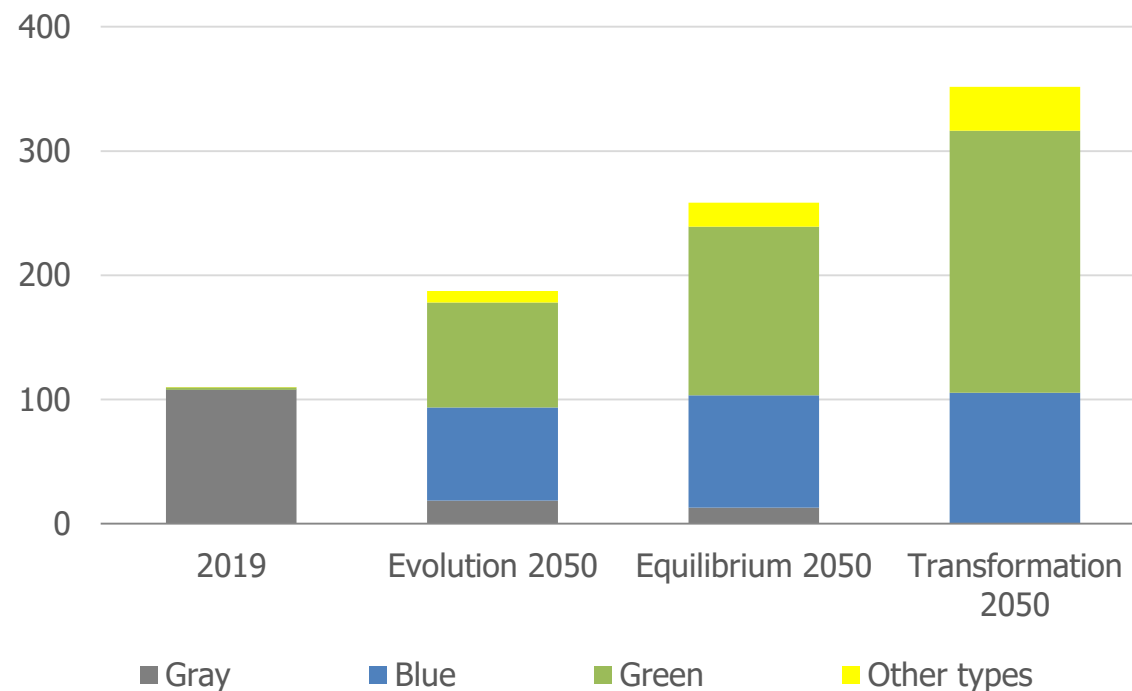
Hydrogen is a prospective solution for sectors that are difficult to decarbonize

Hydrogen demand by sector, Mt



- ▶ The climate policy of the leading industrial countries contributes to the growth of hydrogen consumption as a universal energy carrier
- ▶ The global market of hydrogen and its derivatives may reach 200-350 Mt by 2050
- ▶ The main drivers of demand for hydrogen: industry, transport and power generation

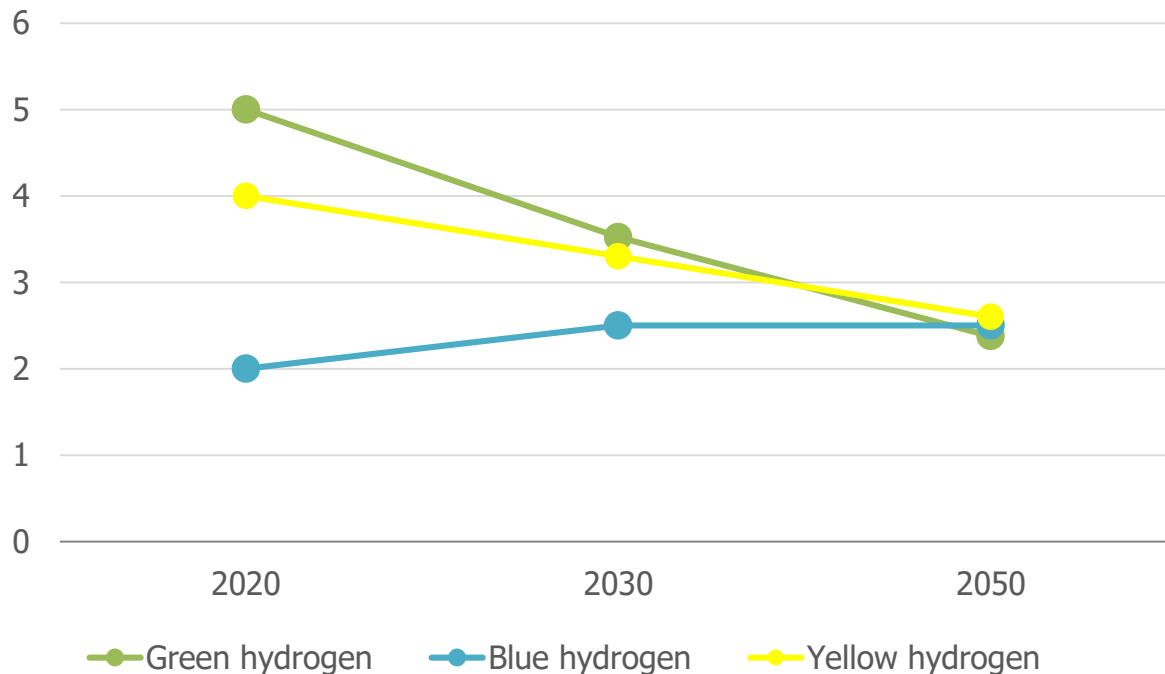
Hydrogen supply by production methods, Mt



- ▶ The growth of the hydrogen market will be accompanied by an increase in the production of clean hydrogen (mainly “green” and “blue”) and reduction in the use of hydrogen production processes with a significant level of CO₂ emissions
- ▶ An increase in the consumption of “blue” hydrogen will contribute to the growth of demand for natural gas

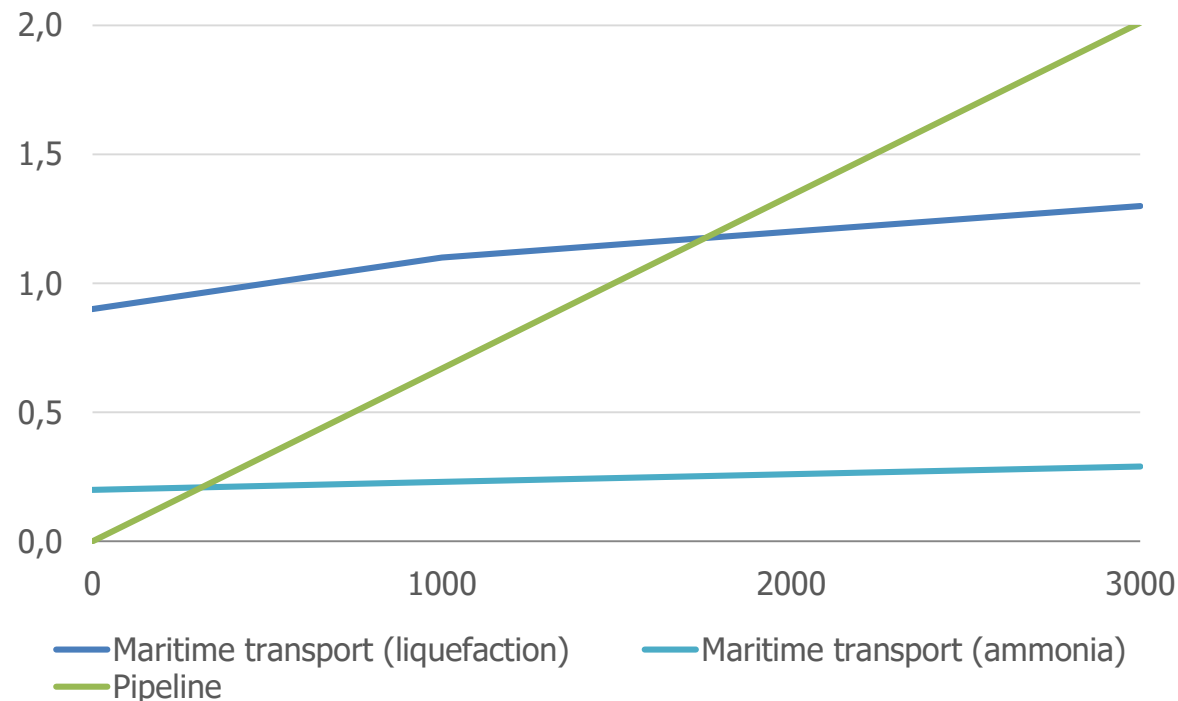
“Green” hydrogen production cost reduction is expected

Levelized cost of hydrogen (LCOH) in Europe, \$/kg



- ▶ Currently, technologies for producing hydrogen from fossil fuels have a cost advantage over green hydrogen produced by electrolysis from renewable energy sources
- ▶ In the long term, a significant reduction in the cost of production of “green” hydrogen is expected due to a decrease in the cost of power generation from RES and a reduction in the cost of electrolyzers

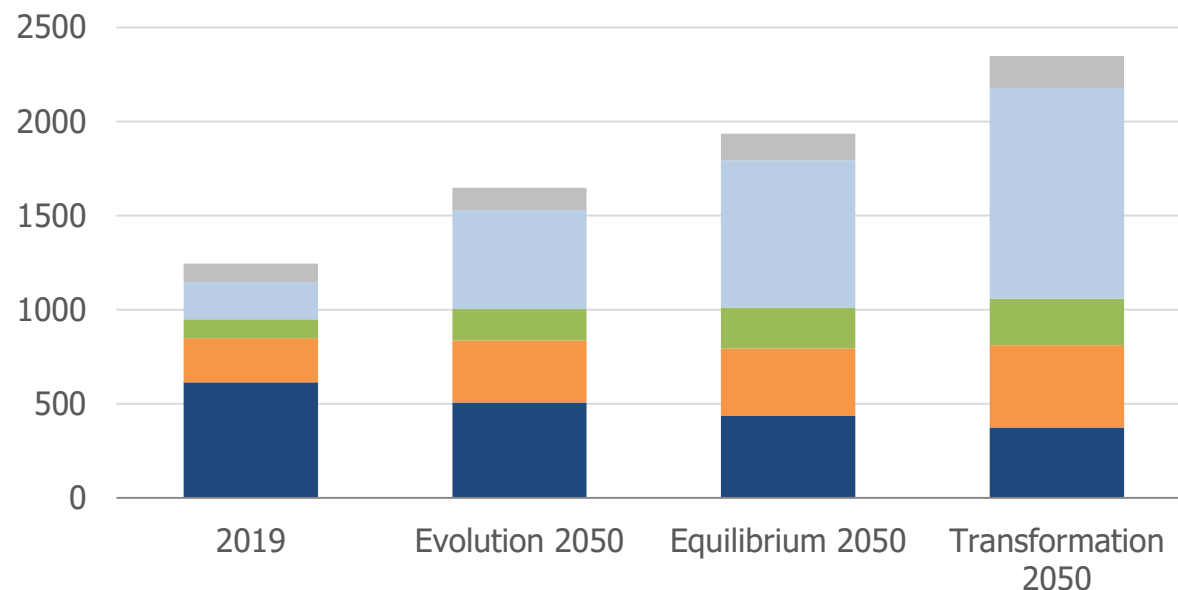
The cost of transporting hydrogen depending on the distance, \$/kg



- ▶ Transportation costs are a significant contributor to the price of hydrogen for end users and can exceed the cost of hydrogen production
- ▶ Many projects in the field of clean hydrogen imply its consumption in the proximity of the production site

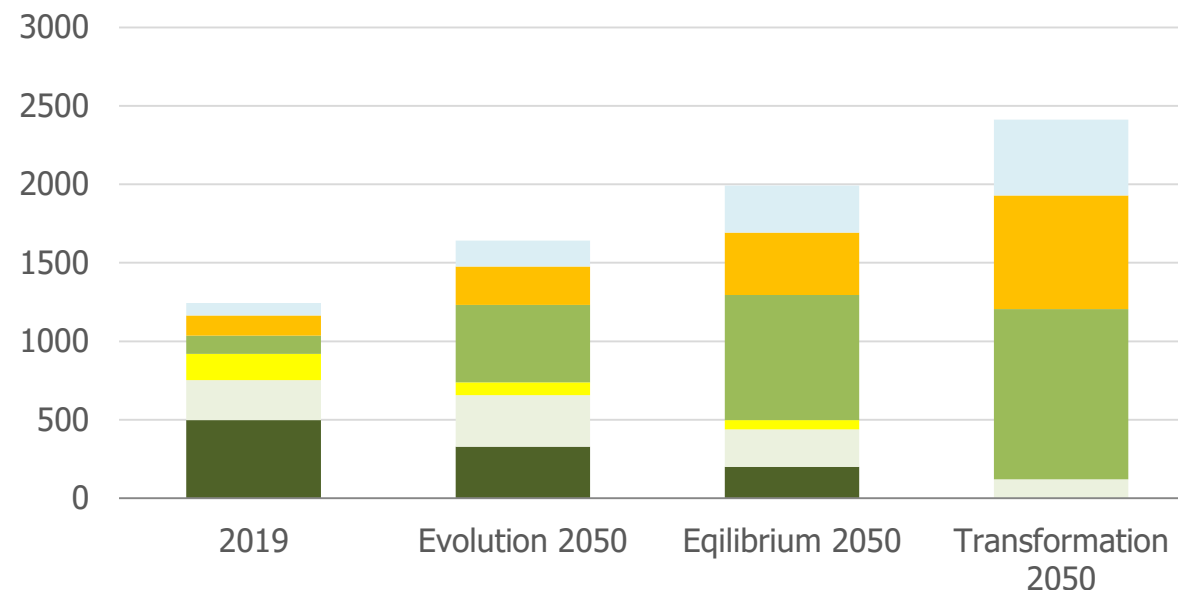
The consumption of modern biomass will increase

Bioenergy demand by sector, Mtoe



- ▶ The transport sector and the power generation sector will support the growth in demand for modern biofuels and biomass
- ▶ Traditional biomass consumption will decline as people access to modern energy sources in developing countries will increase

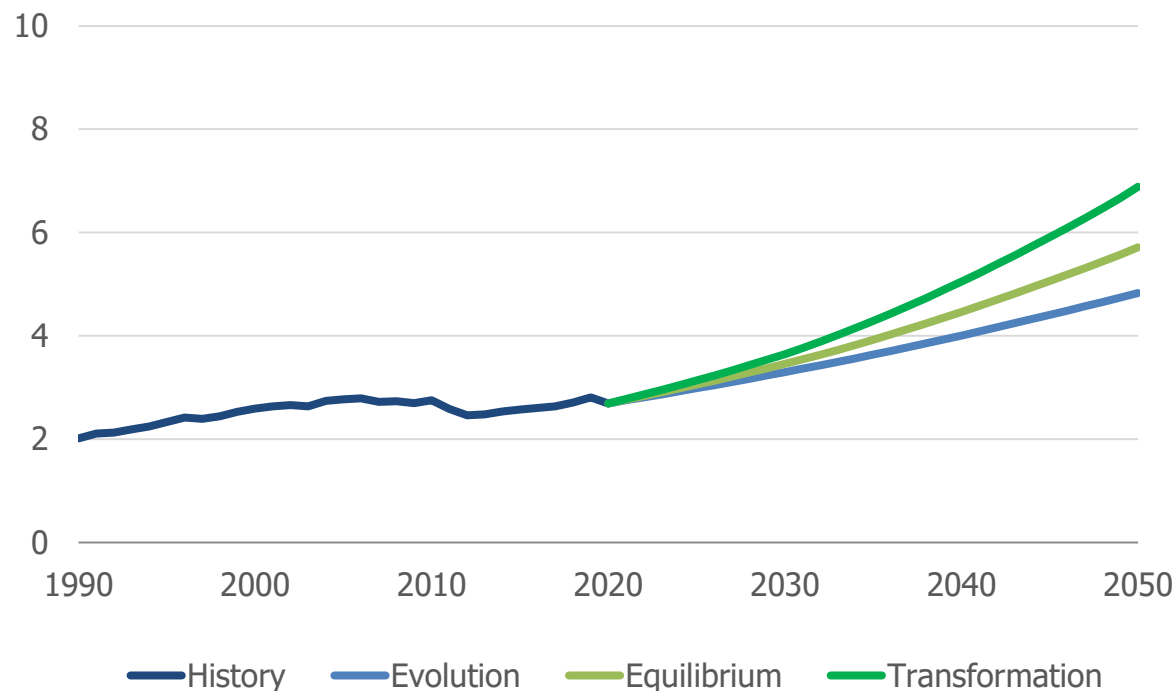
Bioenergy supply by production method, Mtoe



- ▶ The structure of biomass production will evolve towards modern feedstocks
- ▶ Demand will be met mainly by organic waste, woodworking waste and the use of fast-growing plants
- ▶ Increased demand for waste in a tightly supplied market will drive biofuel feedstock prices up

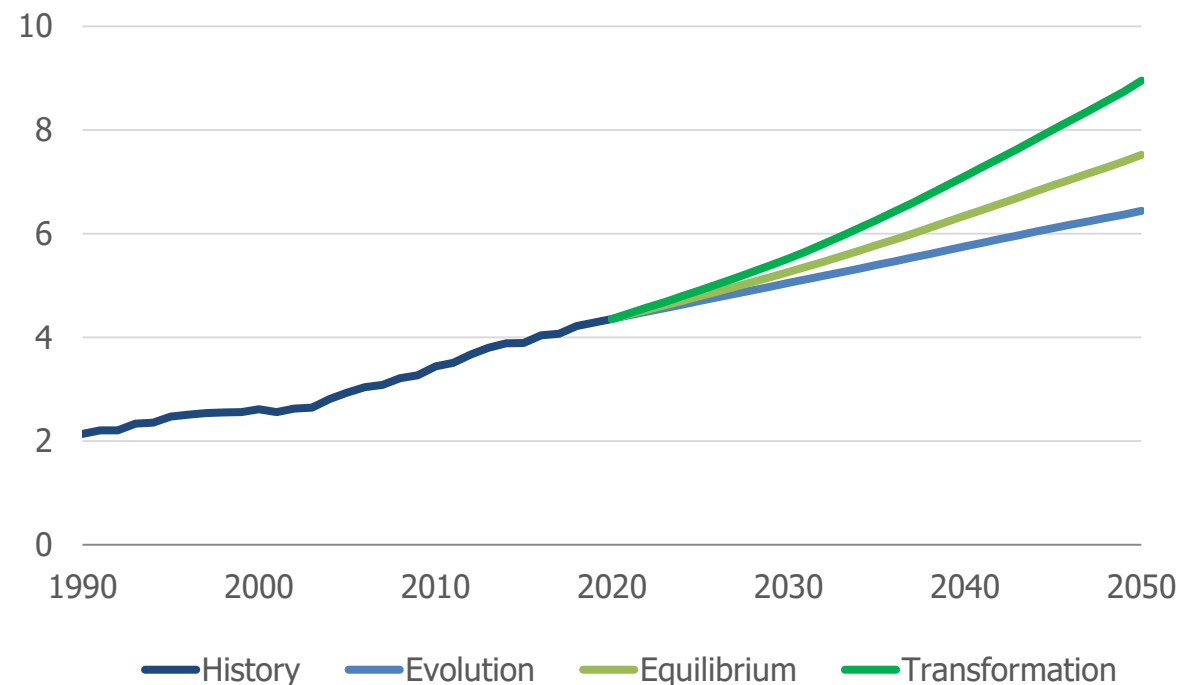
Decarbonization of the energy sector will require an increase in the production of hydro and nuclear energy

Electricity generation at nuclear power plants, thousand TWh



- ▶ Electrification of transport and the use of hydrogen in various sectors of the economy will lead to a significant increase in electricity consumption
- ▶ Hydropower and nuclear technologies have an extremely low carbon footprint. However, in many countries there is a public debate about the sustainability and safety of these types of energy

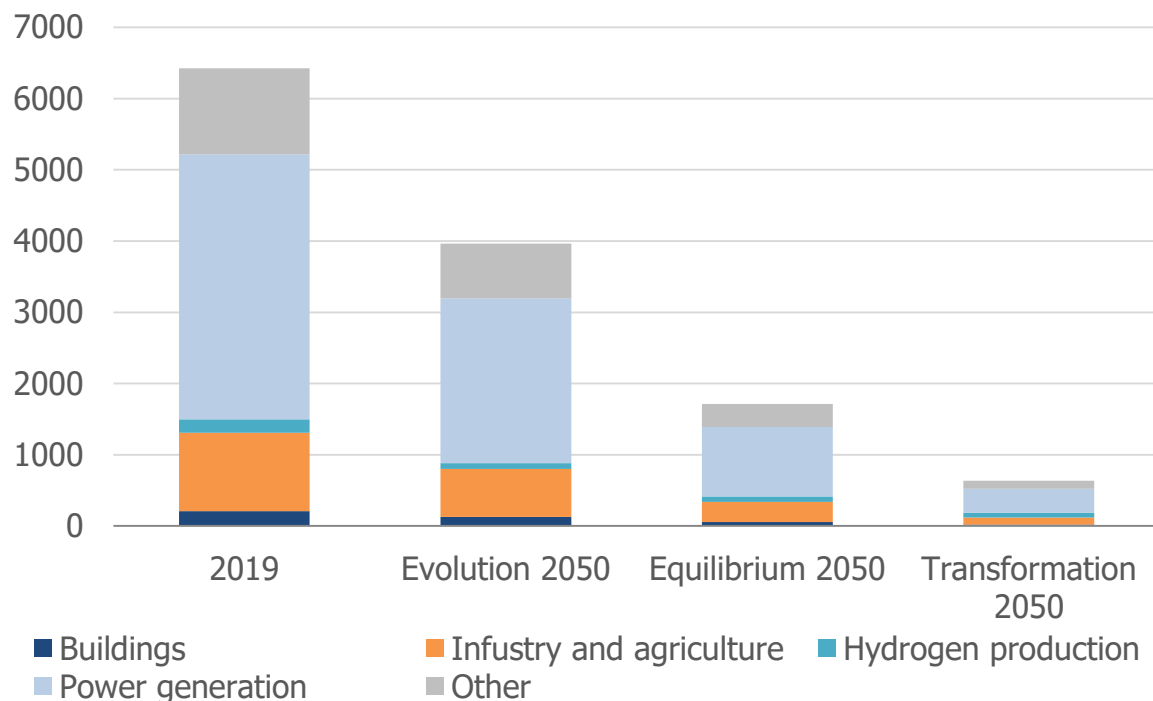
Electricity generation at hydroelectric power plants, thousand TWh



- ▶ Advances in technology can make nuclear and hydropower safer
- ▶ One of the possible directions for the development of hydropower is the construction of tidal power plants
- ▶ Small modular reactors and thermonuclear fusion are considered promising areas in the nuclear industry

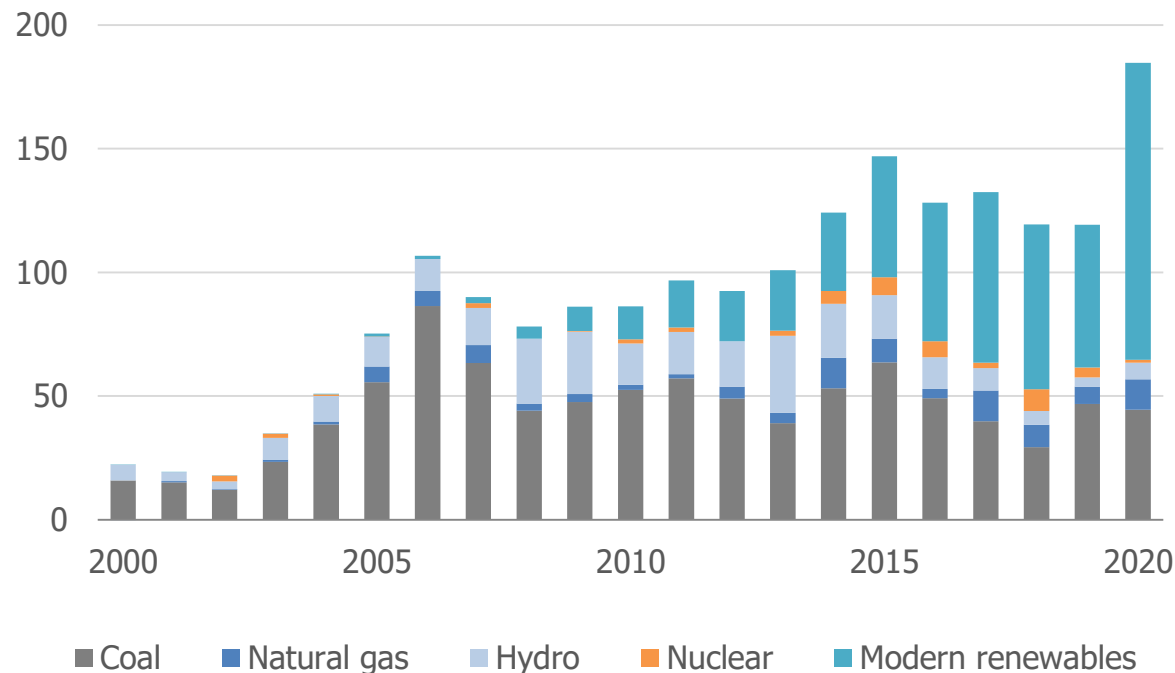
Coal consumption will decline in all considered scenarios

Coal demand by sector, Mt



- ▶ The majority of the world's coal is consumed in the power generation sector
- ▶ Coal has the highest carbon intensity of fossil fuels
- ▶ Climate policy in many countries includes gradual reduction of coal-fired power generation

Net change in power generation capacity in China, GW



- ▶ China as the largest consumer of coal is focusing on decarbonization of the energy sector. However, China continues to commission new coal-fired power plants
- ▶ By signing at COP26 in Glasgow of an agreement that provides for a phased reduction of coal in the energy sector, as well as the introduction of an emissions trading system, China indicates the readiness for more active reduction of coal share in its energy mix



RUSSIAN ENERGY

Russia announced the strengthening of its climate ambitions in 2021

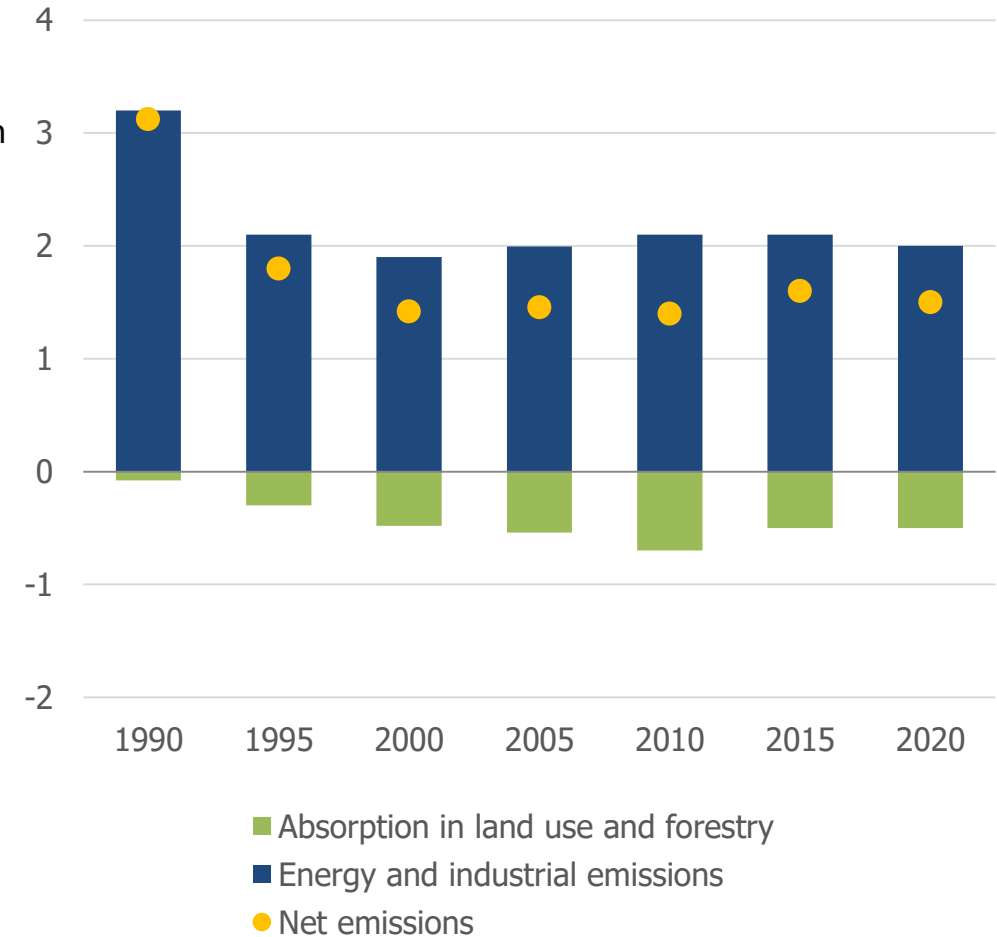
Russia's climate goals

-  Climate neutrality by 2060 or earlier (the previous goal was to reduce emissions by 30% by 2030 from 1990 levels)
-  Lower values of accumulated net greenhouse gas emissions up to 2050 compared to the EU
-  Increasing the share of RES in power generation mix
-  15% share of electric vehicles in new car sales
-  Production of 217 thousand electric vehicles in Russia
-  Hydrogen exports in the amount of 2-12 Mt by 2035 and 15-50 Mt by 2050

Legislative initiatives in greenhouse gas emissions control in Russia

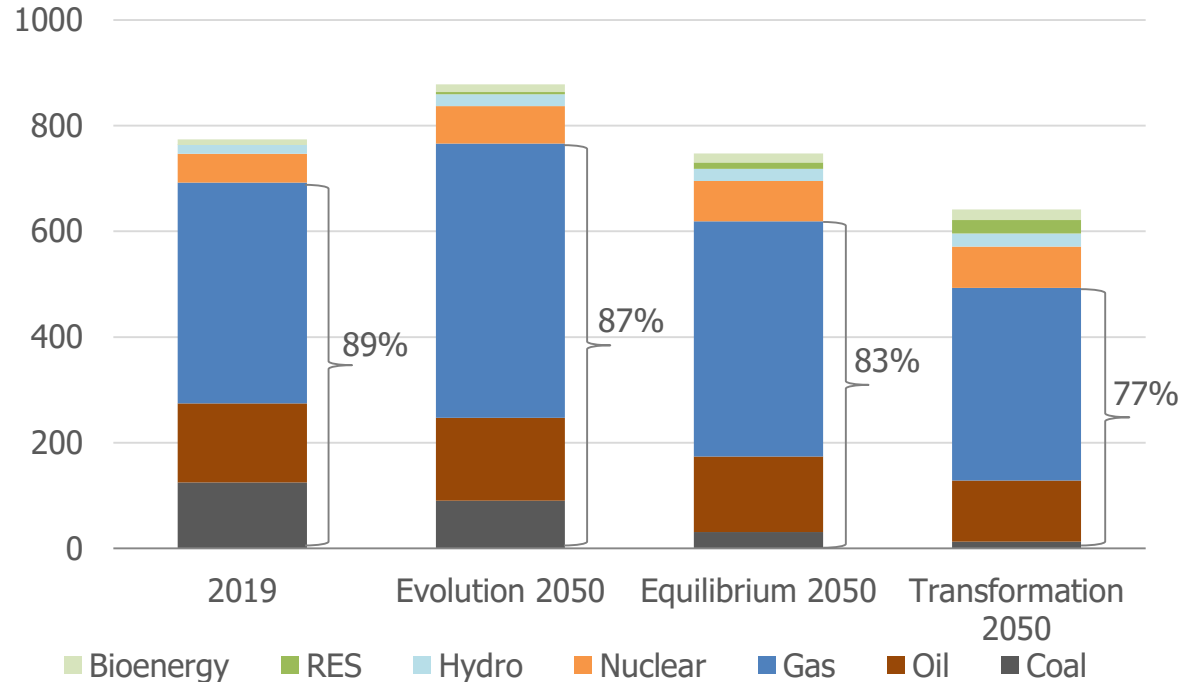
-  The Federal Law on Limiting Greenhouse Gas Emissions has been adopted
-  An experiment is planned to establish a special regulation of emissions and absorption of greenhouse gases in the Sakhalin region
-  It is expected to develop legislation on emission trading and implementation of climate projects

Dynamics of anthropogenic greenhouse gas emissions in Russia, Gt CO₂e



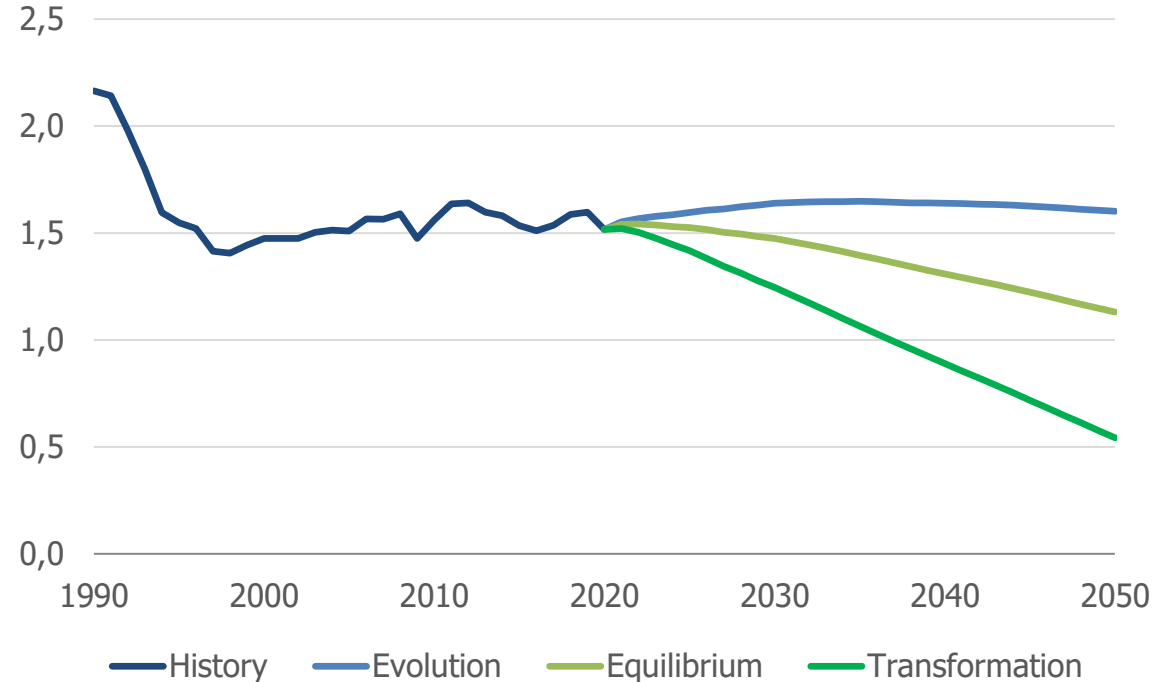
The structure of Russia's fuel balance will gradually change towards an increase in the share of low-carbon sources

Forecasts of primary energy consumption, Mtoe



- ▶ Fossil fuels account for about 90% of Russia's primary energy consumption
- ▶ Over time, the share of coal will decrease, and the share of low-carbon energy sources will grow
- ▶ Gas will remain the dominant energy source regardless of the scenario

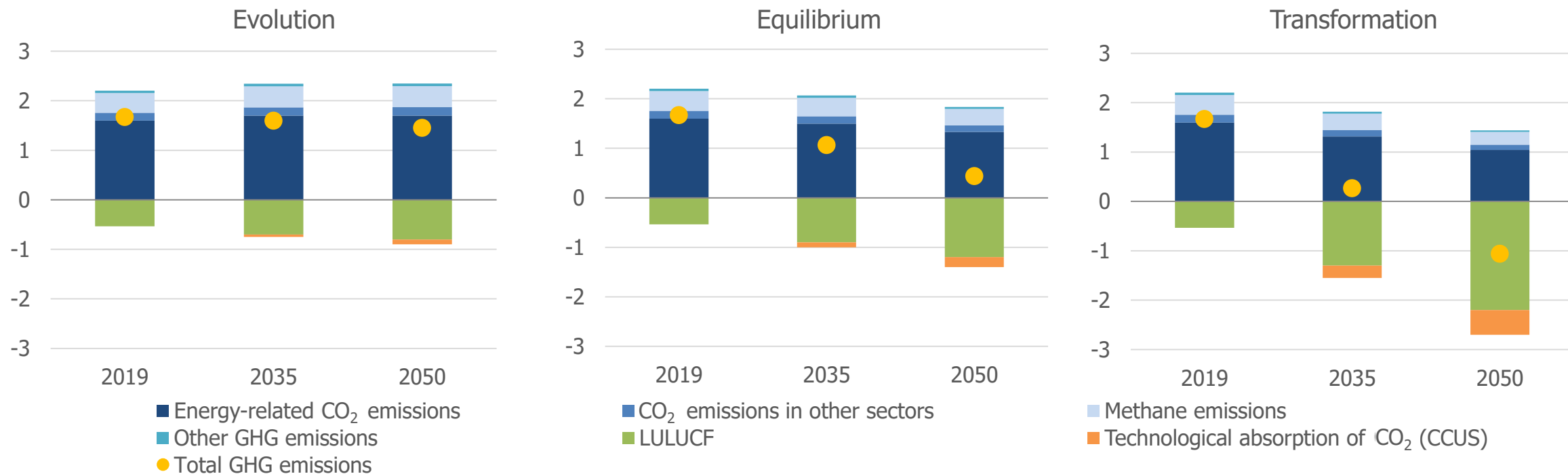
Energy-related CO₂ emissions trends, Gt CO₂e



- ▶ The trajectory of CO₂ emissions in the energy sector will be determined by the fuel structure of the energy balance and the level of energy efficiency
- ▶ The "Equilibrium" scenario is most consistent with the stated goals in the field of emission reduction
- ▶ The "Evolution" scenario takes into account the risks as well as technical and economic constraints associated with achieving the stated goals

Russia has the potential to achieve climate neutrality before 2060

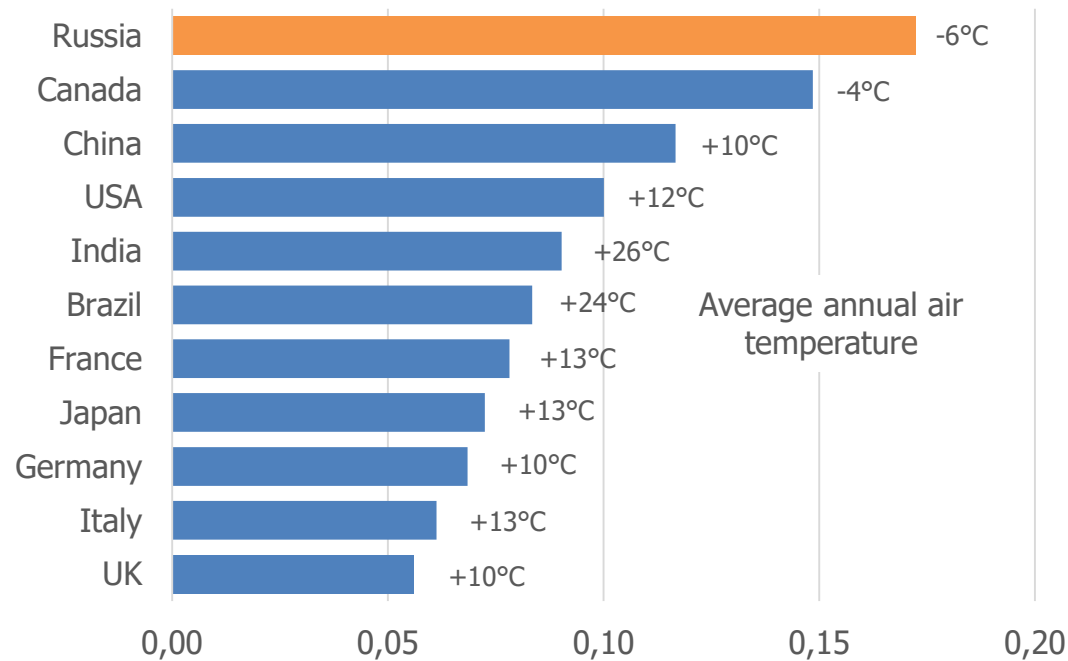
The structure of greenhouse gas emissions in various scenarios, Gt CO₂e



- ▶ Russia's opportunities to achieve carbon neutrality are associated with increasing energy efficiency, reducing methane emissions, increasing the absorption capacity of forests and wetlands, and using CCUS technologies
- ▶ By 2050 the volume of greenhouse gas emissions in Russia, taking into account natural sinks, can range from 1.4 to -1 Gt CO₂e

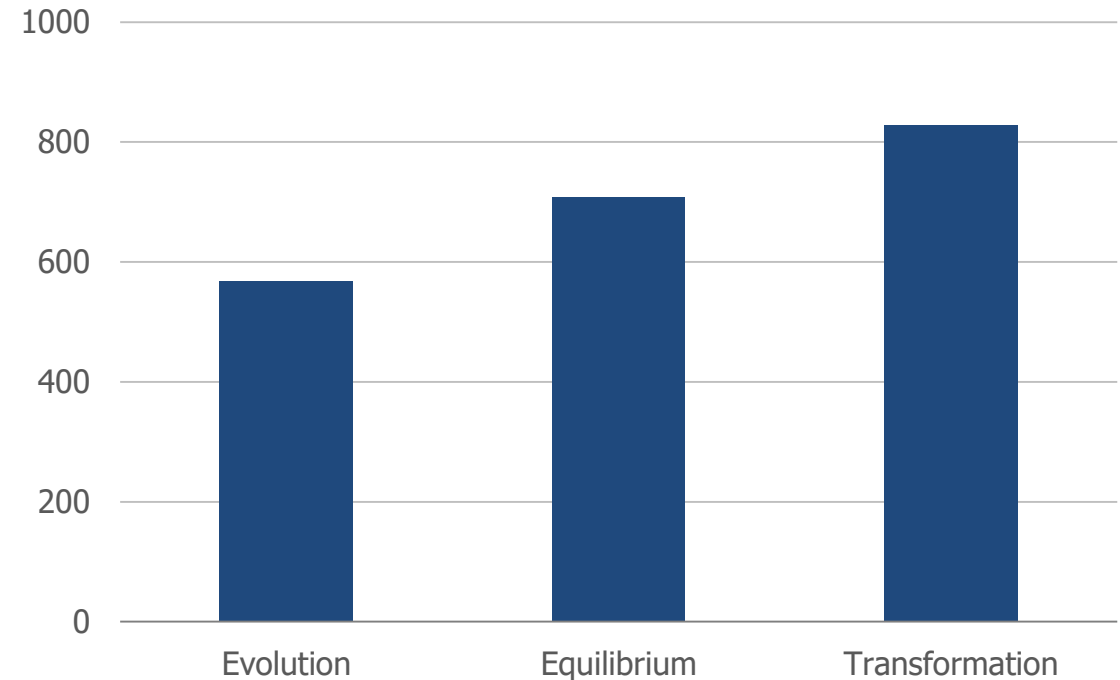
Improving energy efficiency is a promising area to reduce emissions in Russia

Energy intensity of GDP of the largest economies in 2020, toe/1000\$ PPP GDP



- ▶ Russia lags behind many major economies in terms of energy efficiency
- ▶ The main reasons for low energy efficiency are the wear of industrial and power equipment, high energy losses in buildings and constructions

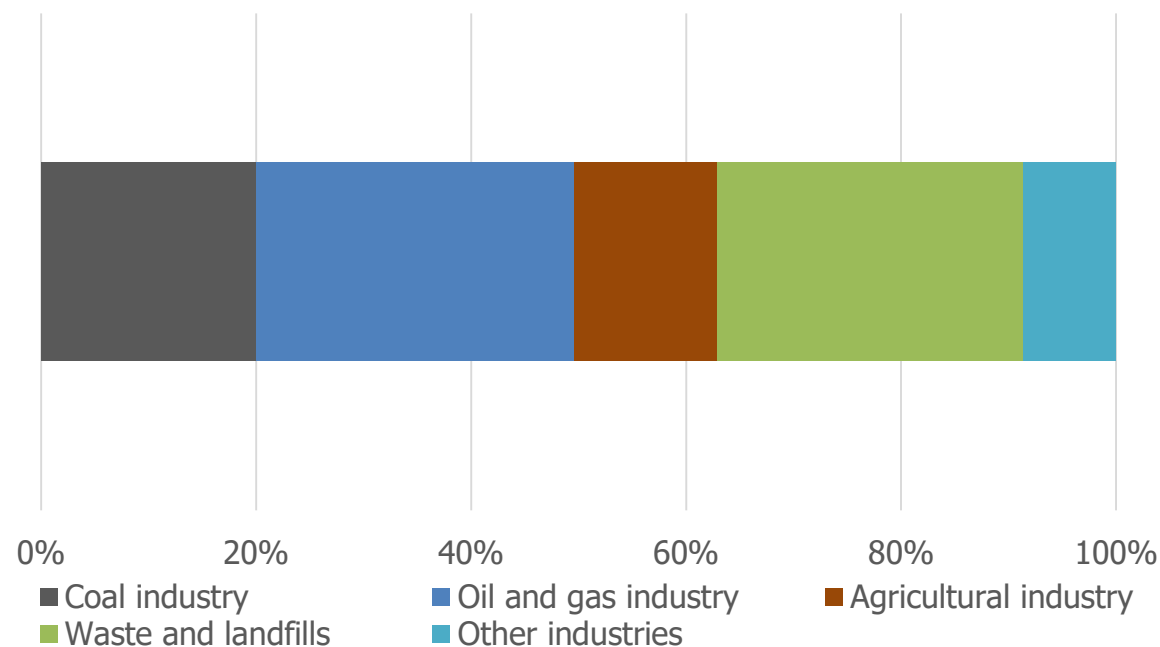
Energy-related CO₂ emission reduction due to energy efficiency improvement in 2020-2050, Mt CO₂e



- ▶ The use of energy-efficient technologies in industry, transport and the sector of residential, commercial and administrative buildings will provide significant reductions in greenhouse gas emissions
- ▶ The expected reduction in emissions due to increased energy efficiency is 570-830 Mt CO₂e depending on the scenario

Russia can significantly reduce methane emissions in the oil and gas sector

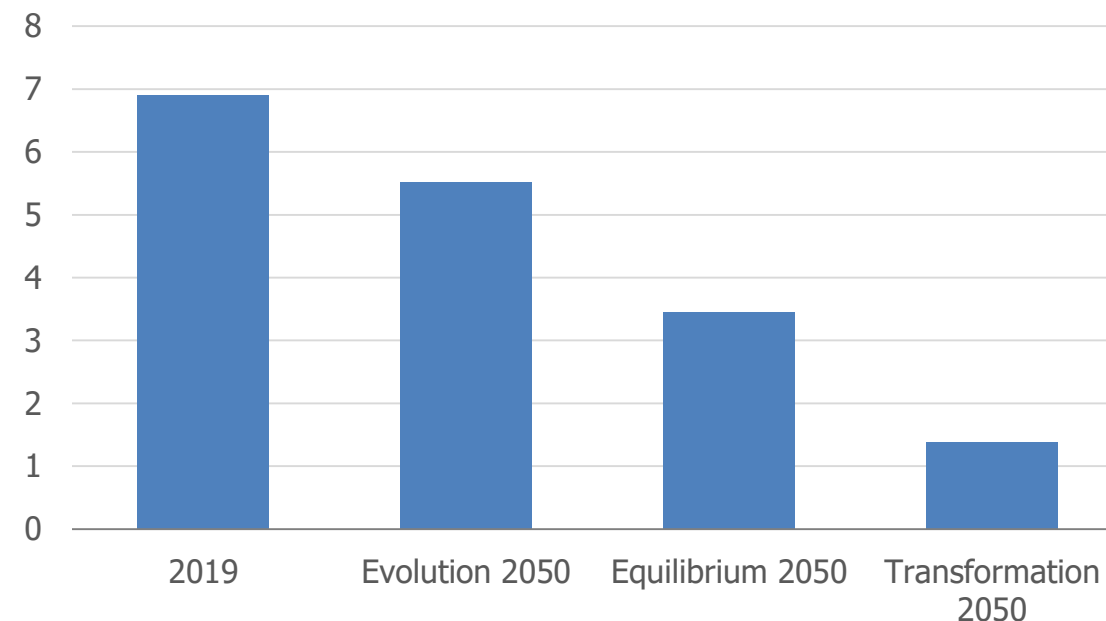
Methane emissions in Russia by industry in 2019, %



Source: Roshydromet

- ▶ The oil and gas sector accounts for about a quarter of Russia's greenhouse gas energy emissions
- ▶ According to Roshydromet data, in 2019 the volume of fugitive emissions in the oil and gas industry was estimated at 148 Mt CO₂e , most of which is methane emissions

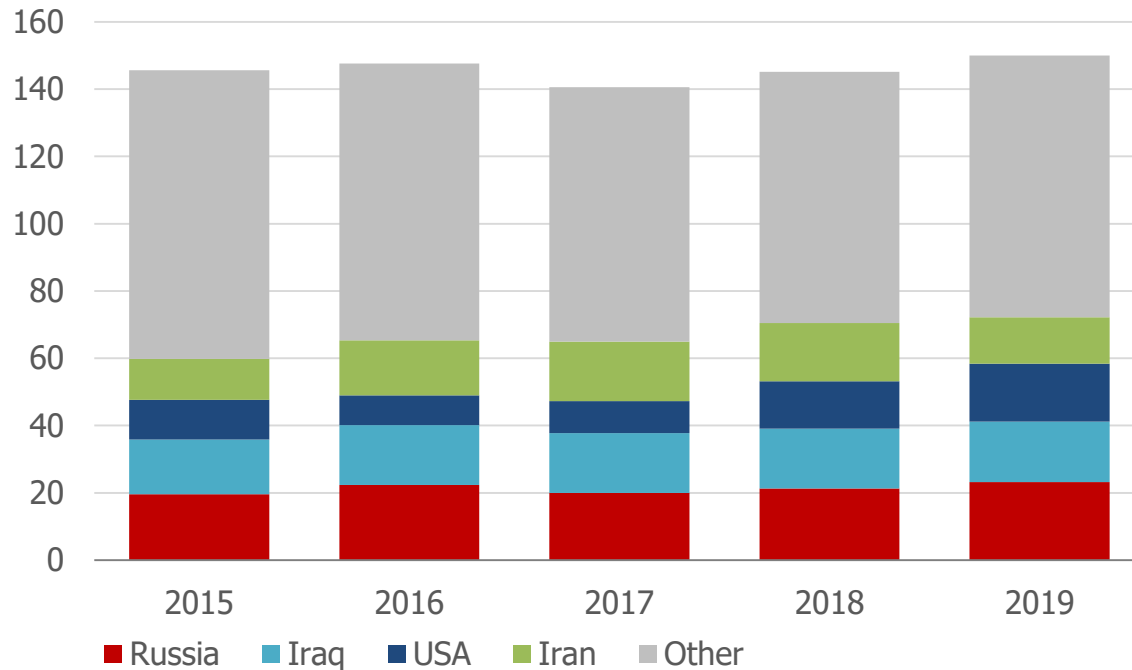
Methane emissions in the oil and gas sector, Mt



- ▶ Methane emissions in the Russian oil and gas sector can be reduced by upgrading equipment and using modern monitoring systems
- ▶ A significant part of such projects is cost-effective even in the absence of incentives from the climate legislation

An increase in the volume of associated petroleum gas utilization will lead to a reduction in energy sector CO₂ emissions in Russia

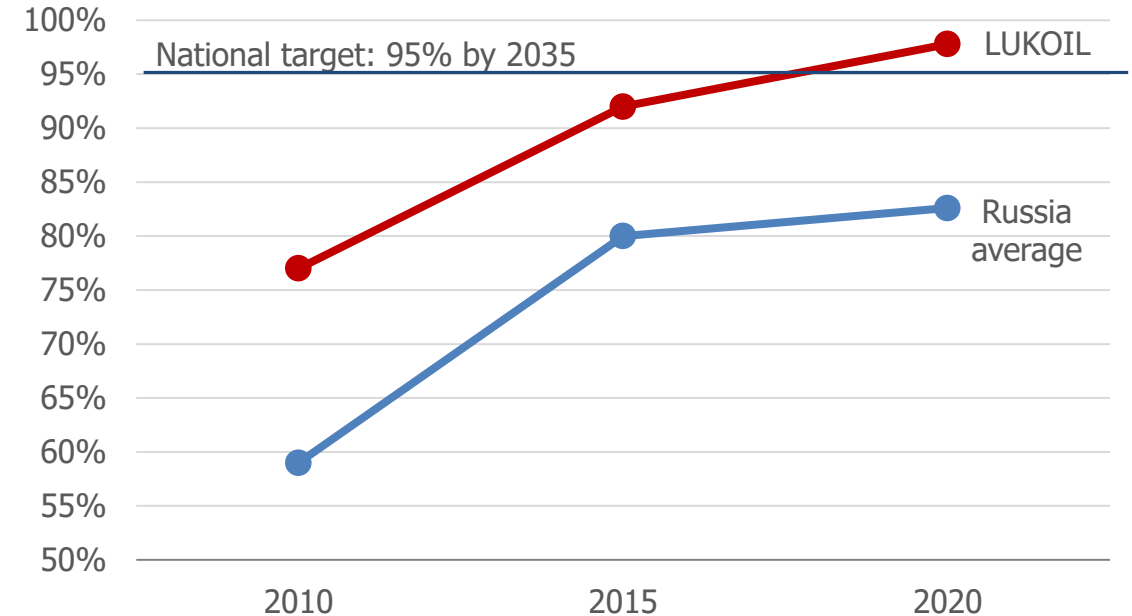
Gas flaring volume by country, bcm



Source: The World Bank

- ▶ Russia is one of the world leaders in gas flaring volumes along with countries such as Iraq, Iran and the USA
- ▶ Over the past decade, significant progress has been made in the field of the useful use of associated petroleum gas (APG): the level of APG utilization increased from 59% in 2010 to 83% in 2020

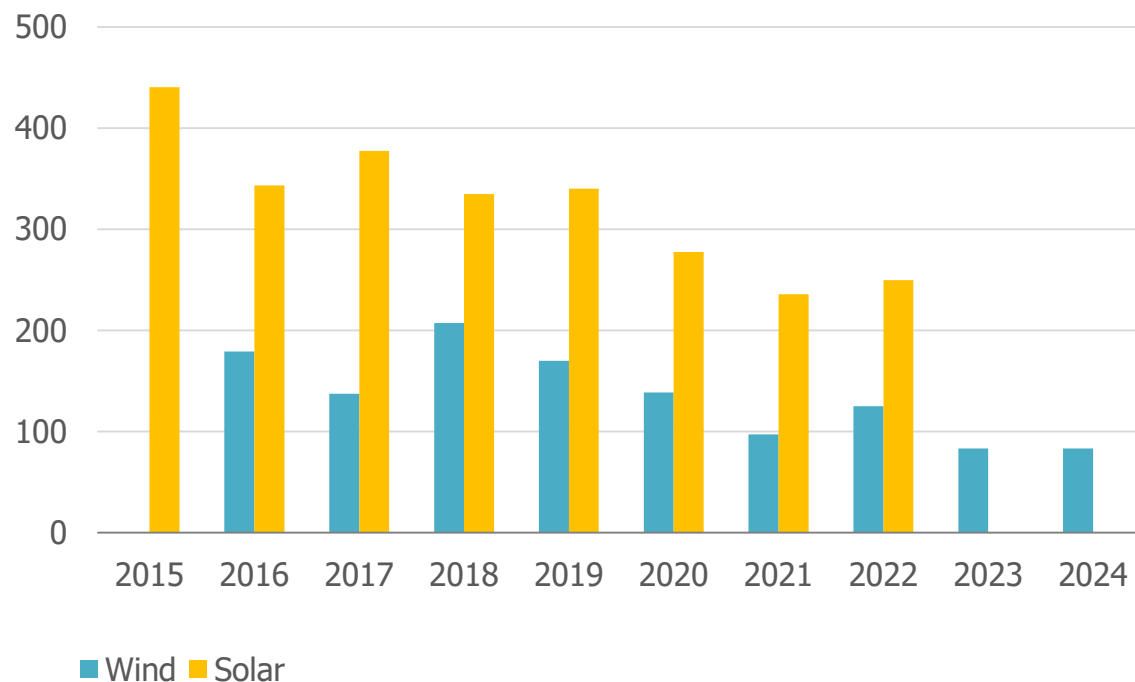
The level of associated petroleum gas utilization in Russia, %



- ▶ Despite the adoption of a number of legislative incentives, the level of APG utilization in Russia is still below the target value of 95%
- ▶ It is possible to achieve this target through the implementation of projects for APG injection into the reservoir to increase oil recovery, the supply of APG to power generation and gas processing facilities

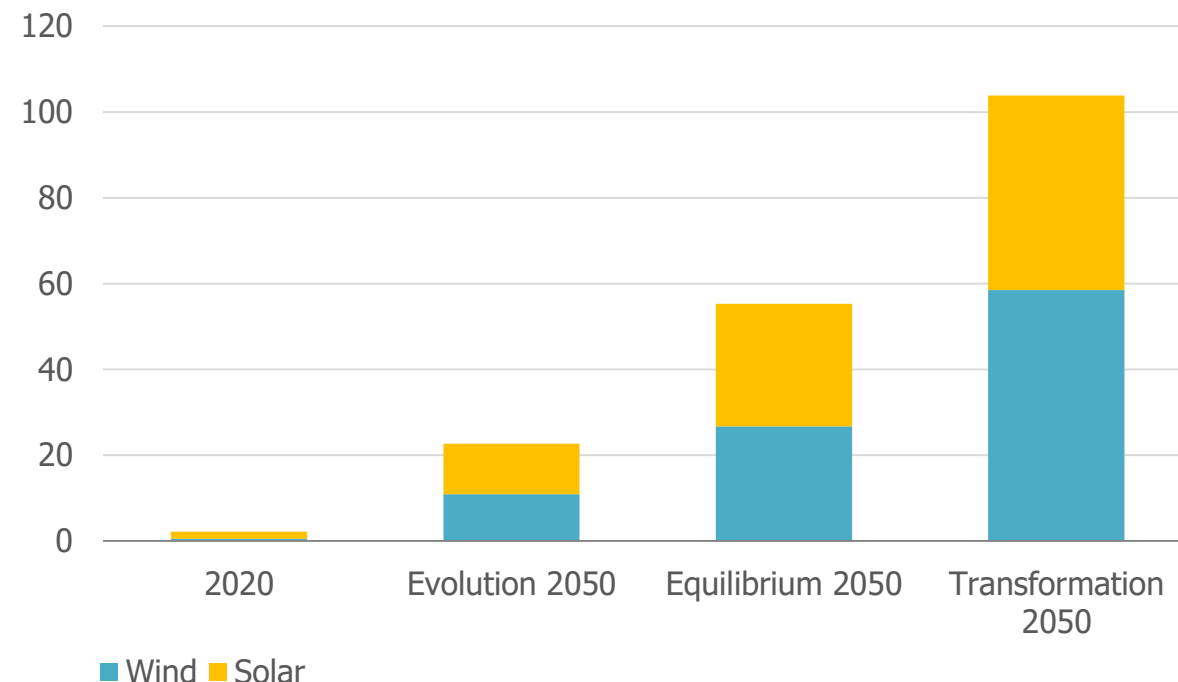
The role of modern RES in Russian energy sector will increase

Levelized cost of energy (LCOE) of RES in Russia, \$/MWh



- Levelized cost of energy from RES in Russia is higher than the global average, largely due to the high cost of capital and the need for localization of production
- As the industry develops, there is a tendency to reduce the cost of energy production from renewable sources

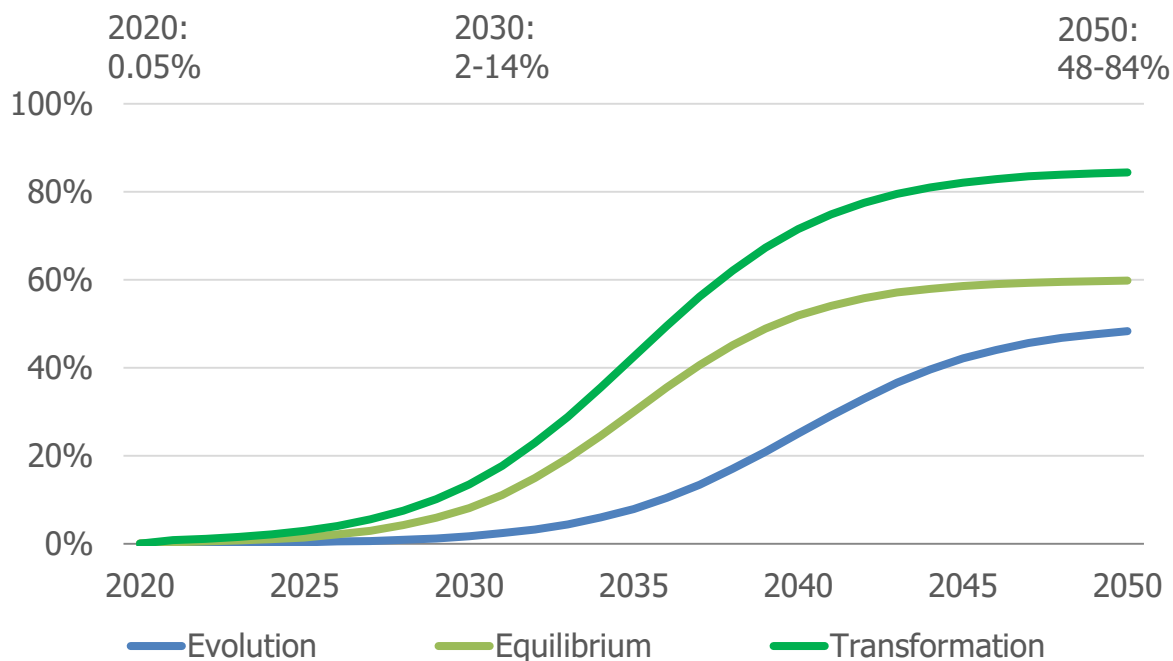
Actual and forecast capacities of modern RES in Russia according to scenarios, GW



- It is expected that various measures to support the renewable energy industry in Russia will continue in the medium term
- The annual capacity growth will depend on the rate of reduction in the cost of electricity from RES and economic incentives in place

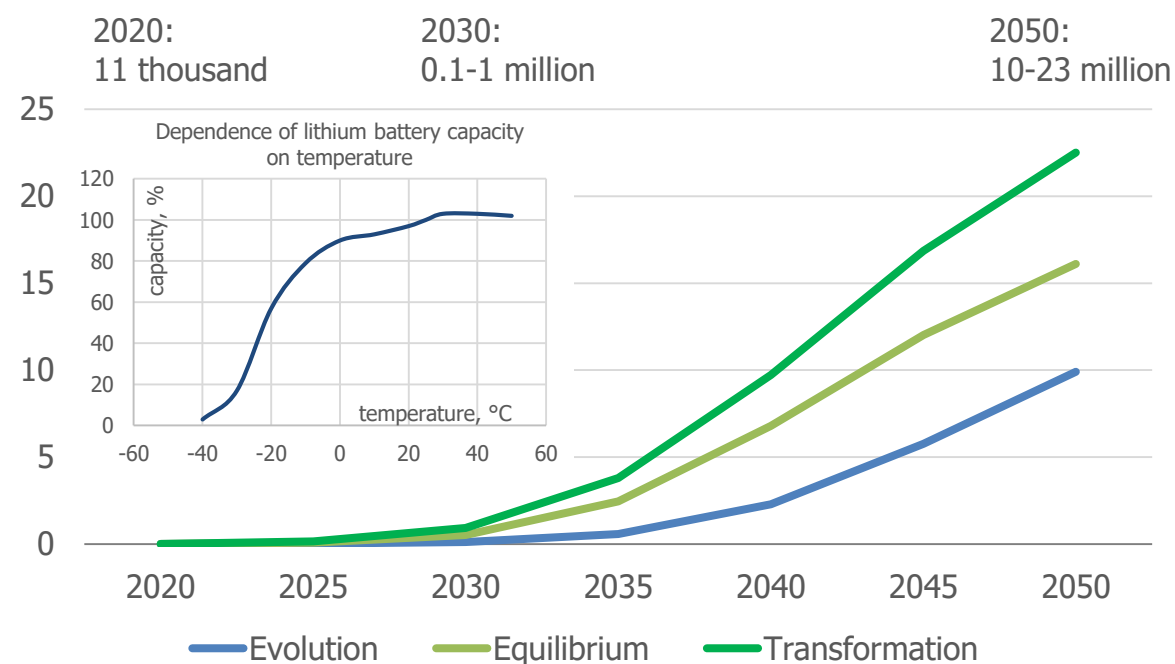
Electrification of car fleet in Russia will go slower than in Europe

The share of electric vehicles (BEV+FCEV) in passenger car sales, %



- ▶ By the end of 2020, 687 passenger battery electric vehicles were sold in Russia: 0.05% of total sales
- ▶ The total fleet of passenger electric vehicles by the end of 2020 amounted 11 thousand units or 0.03% of the total size of the fleet
- ▶ In the commercial segment, electric vehicles are practically not used except for electric buses in Moscow

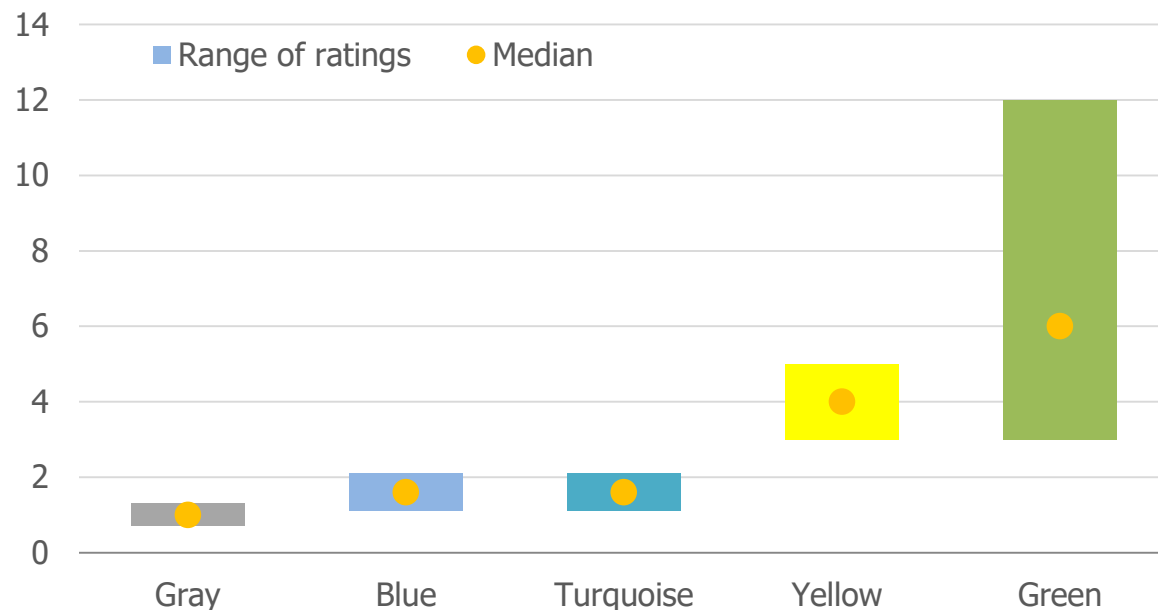
Passenger electric vehicles fleet forecast, mln units



- ▶ In the next decade, the growth in sales of electric vehicles will fall on the premium segment, which accounts for about 10% of the total sales of passenger cars in Russia
- ▶ The most likely scenario is the "Evolution", according to which by 2030 the fleet of electric vehicles in Russia will total 100 thousand units (a 10 times growth compared to 2020)

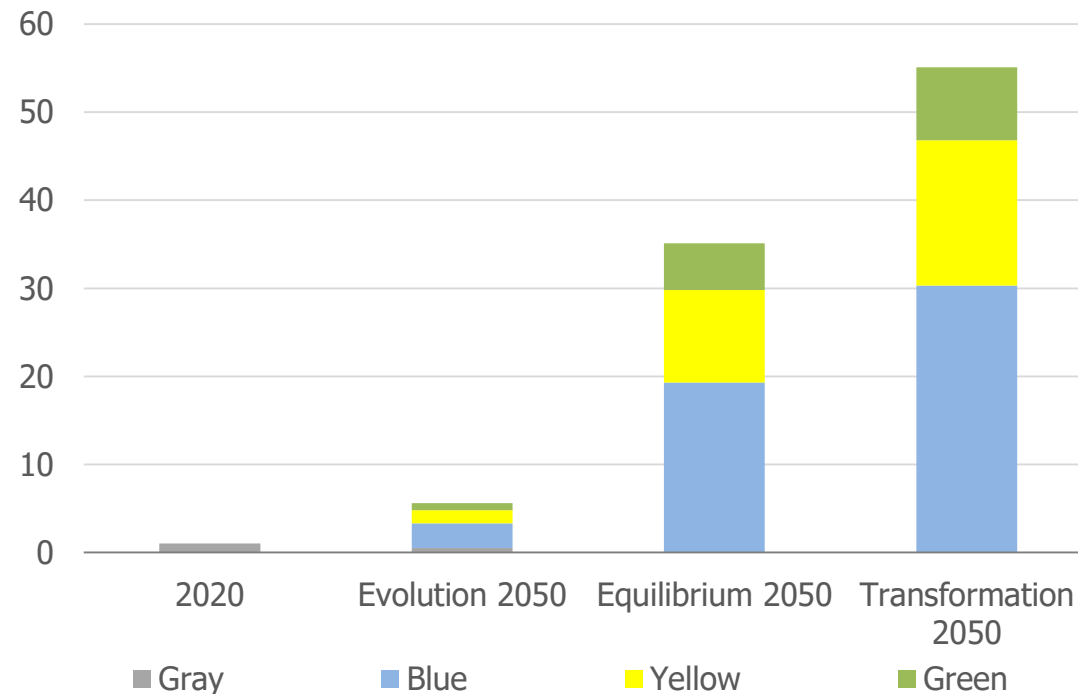
Russia plans to increase the production of low-carbon hydrogen

The cost of hydrogen production in Russia in 2020, \$/kg



- ▶ Russia has the resource potential to produce low-carbon hydrogen both from fossil fuels and using renewable energy sources
- ▶ Hydrogen produced using renewable energy is currently the most expensive. However, we can expect a gradual reduction in its cost

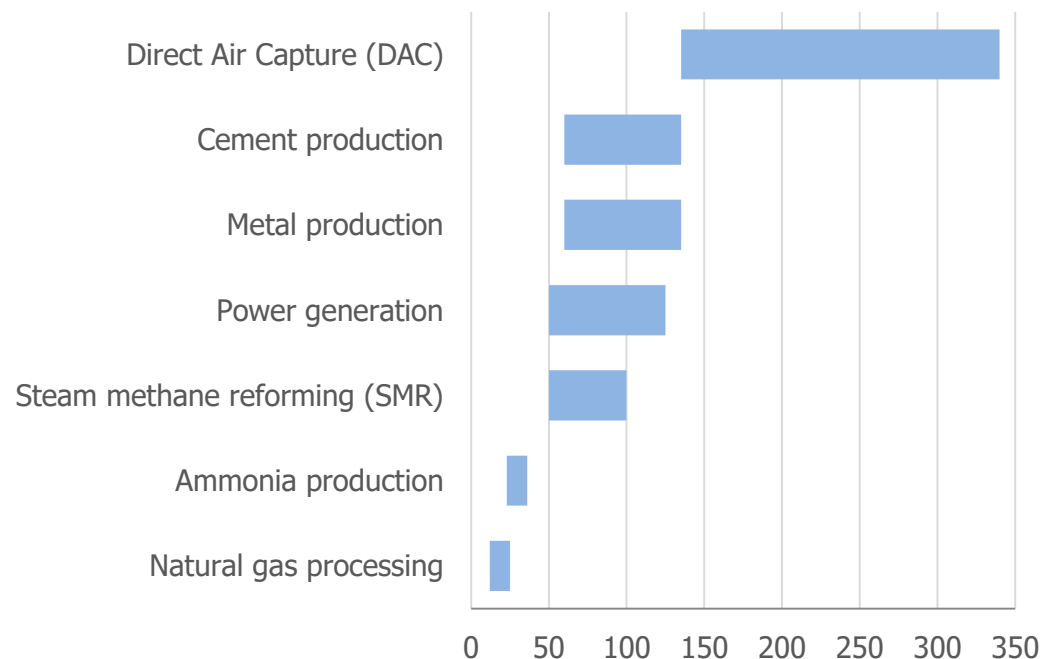
Hydrogen production in Russia according to scenarios, Mt



- ▶ The volume of hydrogen production in Russia will depend on the amount of demand for hydrogen in foreign markets and within the country
- ▶ The high cost of transporting hydrogen over long distances is a significant limitation for the export of hydrogen from Russia

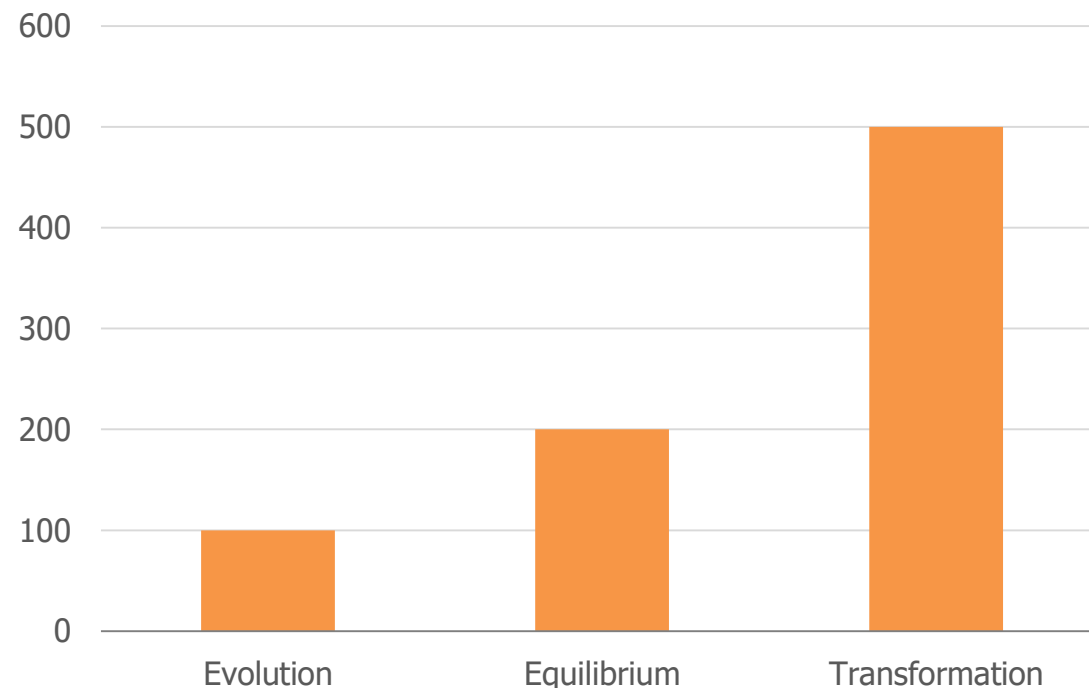
CCUS technologies can provide a significant amount of emission reduction in Russia

CO₂ prices required to ensure the profitability of CCUS projects, \$/t



- ▶ Russia has the highest CO₂ storage potential in the world, which is estimated at 1000-1200 GT of CO₂ mainly in oil and gas deposits and aquifers
- ▶ The high cost of CO₂ capture and transportation hinders the use of CCUS technologies in Russia

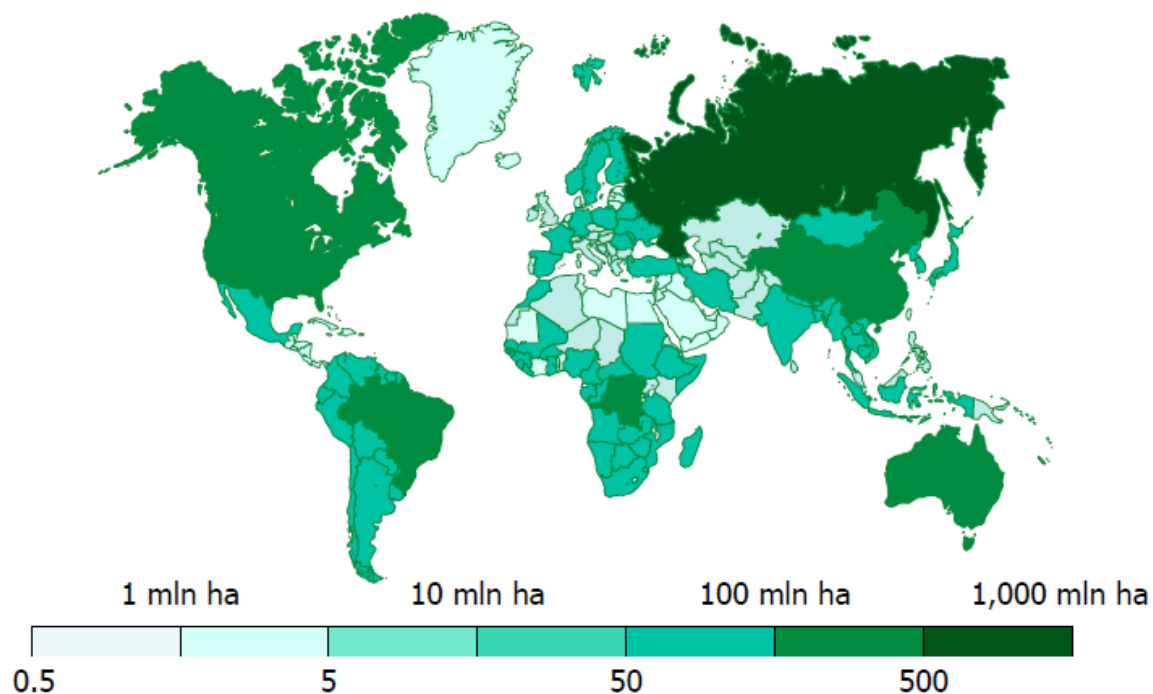
CCUS emission reduction by 2050 according to scenarios, Mt CO₂e



- ▶ The use of CO₂ to increase oil recovery makes it possible to increase the investment efficiency of CO₂ capture projects
- ▶ The reduction of emissions from the implementation of CCUS projects in Russia may amount to from 100 to 500 Mt CO₂e by 2050

Large forest areas allow Russia to become a world leader in the use of natural CO₂ sinks

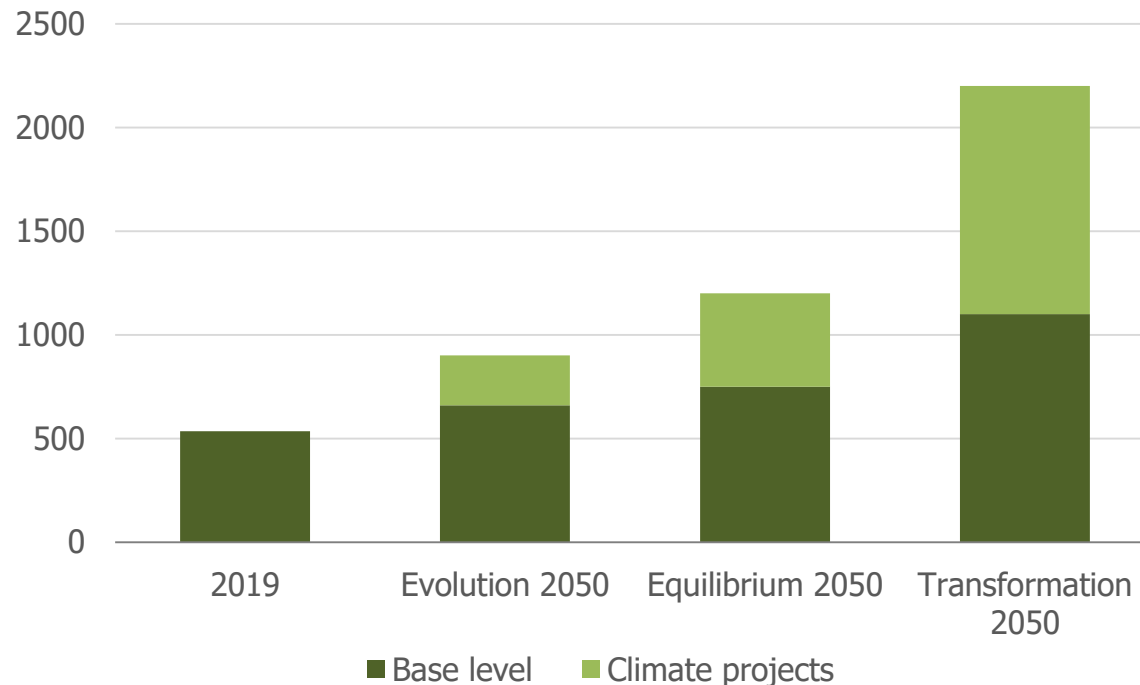
Forest areas by country, mln ha



Source: Our World in Data

- ▶ Russia ranks first in the world in terms of the area of forests that are natural sinks of carbon dioxide
- ▶ As of 2019, the absorption capacity of Russian forests was estimated at 535 Mt CO₂e

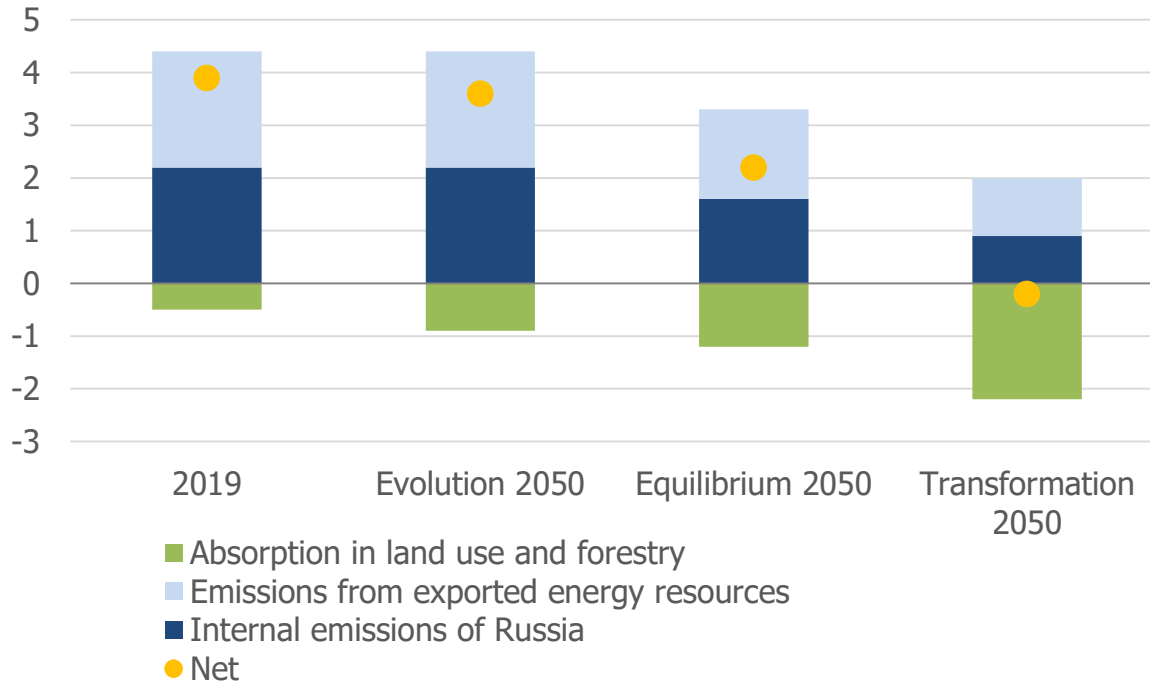
Absorption capacity of Russian forests according to scenarios, Mt CO₂e



- ▶ According to existing estimates, the absorption capacity of Russian forests can be increased to 2.2 Gt CO₂e due to a more complete accounting of the forest stock and the implementation of forestry projects
- ▶ In the "Transformation" scenario, approximately half of the volume of natural CO₂ absorption is achieved through the implementation of climate projects

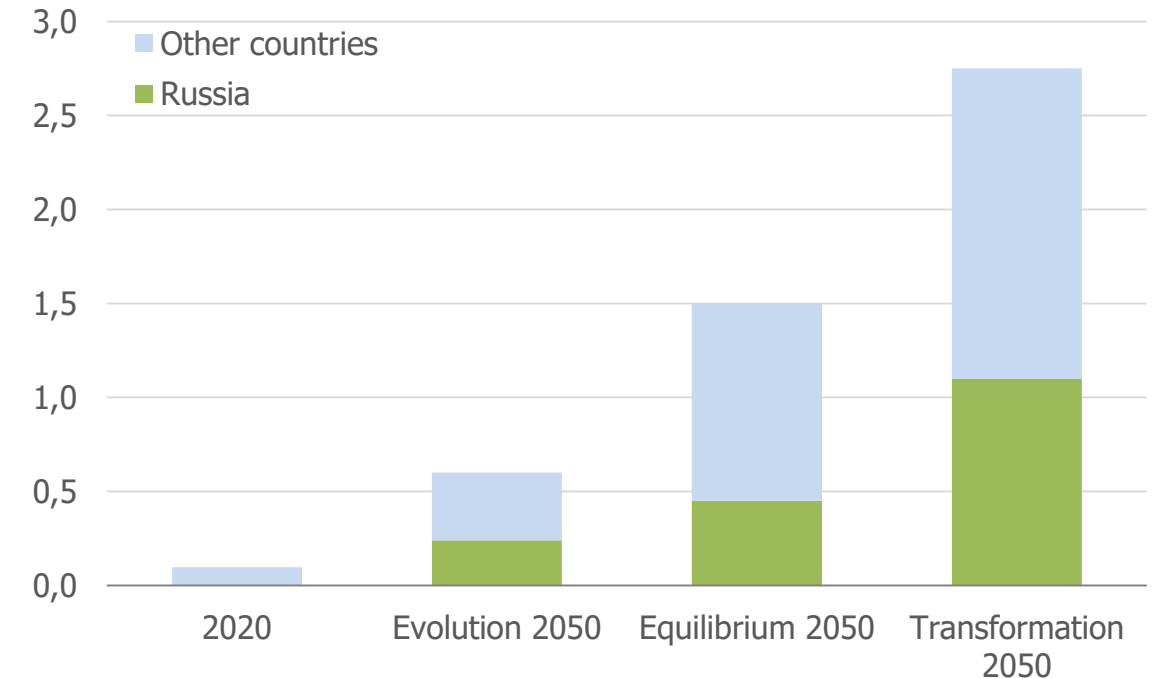
The sequestration potential of Russian forests makes it possible to fully compensate for domestic emissions and emissions from exported energy resources

Russian emissions including emissions from exported energy resources, Gt CO₂e



- ▶ Russia is the largest energy exporter. Consumption of Russian hydrocarbons outside of Russia creates a significant volume of emissions, which is comparable to domestic
- ▶ Increasing the absorption capacity of Russian ecosystems makes it possible to compensate not only for emissions in Russia, but also to offset carbon footprint from energy exports

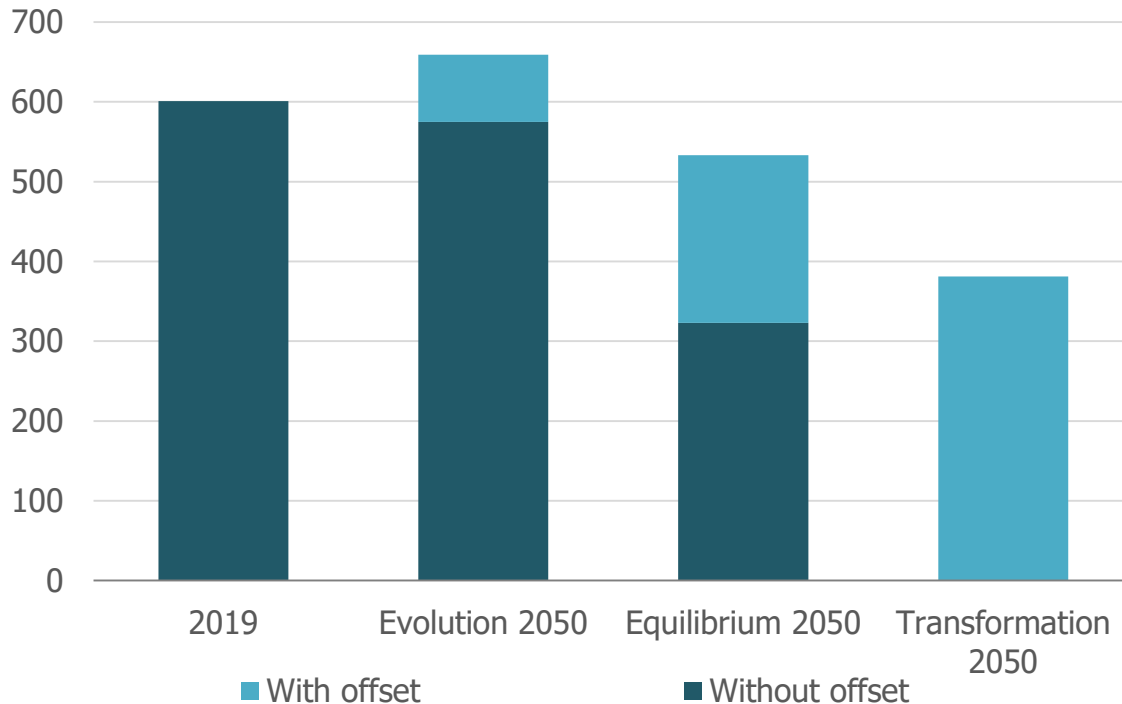
Volume of the global voluntary carbon market, Gt CO₂e



- ▶ The voluntary emissions market has been growing rapidly over the past few years due to the initiatives of the corporate sector
- ▶ The harmonization of the rules of international emissions trade under Article 6 at the COP 26 climate conference will boost the further development of the voluntary carbon market
- Russia can take up to 40% share of the international emissions market

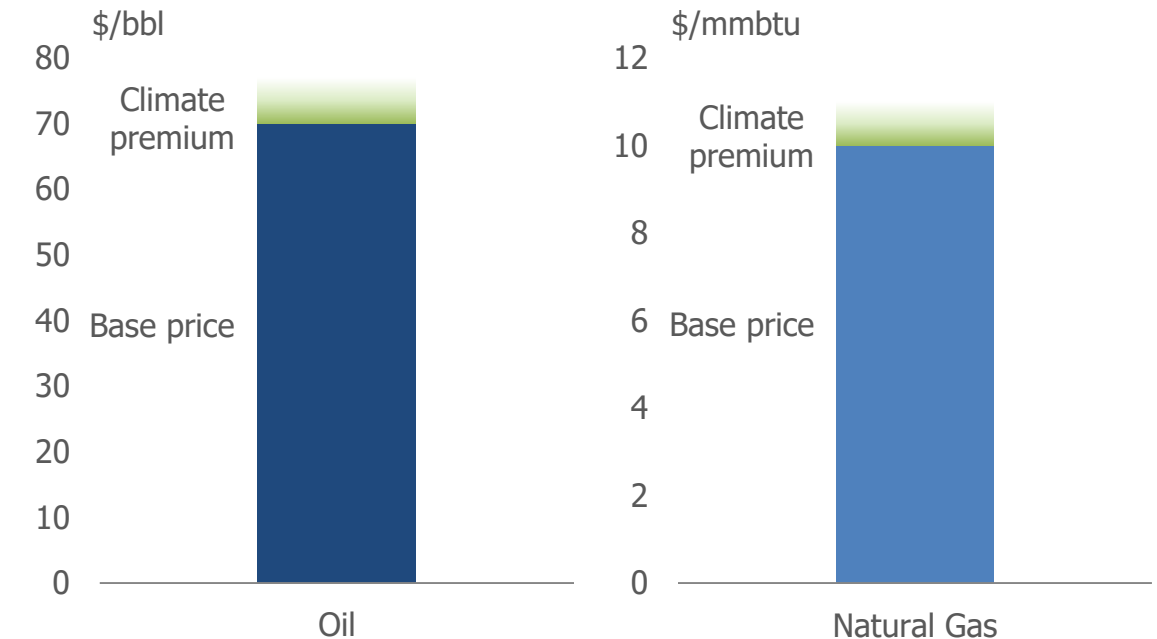
Russia is capable of becoming the largest supplier of hydrocarbons with an extinguished carbon footprint

Export of Russian hydrocarbons according to scenarios, Mtoe



- ▶ Achieving carbon neutrality in the scenarios under consideration involves the use of petroleum products with an extinguished carbon footprint
- ▶ Russian exporting companies are able to significantly reduce the volume of emissions from consumers of their products abroad through use of voluntary emission certificates

Cost estimation of hydrocarbons with extinguished carbon footprint*



* With the cost of certificates at the level of \$10/t CO₂e

- ▶ Prices for products of the oil and gas sector with extinguished carbon footprint will strongly depend on the costs required for the implementation of climate projects
- ▶ The development of the international emissions market will allow reducing CO₂ emissions at the lowest cost by choosing the most effective climate projects

Key findings

- ▶ The world community is facing a serious challenge, on one hand, with the need to provide affordable energy to the growing population of the Earth, and, on the other hand, with the need to reduce greenhouse gas emissions to limit global temperature rise.
- ▶ The coronavirus pandemic and the energy crisis of 2021 have revealed the importance of fossil fuel supplies stability.
- ▶ The high level of energy inequality complicates the process of decarbonization of global economy. The gap in energy consumption per capita between developed and developing countries remains high, despite some reduction in the last decade.
- ▶ Achieving carbon neutrality will require considerable investments in the energy industry, in an annual volume several times higher than the level of investments in recent years. The need to ensure the return of these investments will lead to an increase in the cost of energy for consumers.
- ▶ To significantly reduce greenhouse gas emissions, it is necessary not only to change the structure of the energy balance, increasing the production of energy from renewable sources, but also to actively use technologies for absorbing carbon dioxide, both industrial and natural.
- ▶ The electrification pace of the global car fleet will determine the dynamics of global demand for liquid hydrocarbons. Regardless of the demand scenario, the need for investments in new projects for the production of liquid hydrocarbons persists due to the natural decline in production at existing fields.
- ▶ Within stable or declining market for liquid hydrocarbons, projects with low cost and low carbon footprint will be in demand. A significant part of the reserves with high production costs, including the Arctic offshore, bituminous sands and heavy oil, may not be developed.
- ▶ Demand for natural gas is expected to grow at a higher rate than the demand for liquid hydrocarbons. Trends such as increased electricity consumption and the use of gas for hydrogen production will support the demand for natural gas.
- ▶ The production of energy from renewable sources will grow at a high rate due to the improvement of technologies, cost reduction and government support measures.
- ▶ Russia can be essential to achieving the global goal of reducing emissions, since the absorbing capacity of Russian ecosystems makes it possible to compensate not only for domestic emissions, but also to extinguish the carbon footprint from energy exports, i.e. to help Russia's trading partners to reduce their emissions.



ANNEX

Main assumptions of the LUKOIL scenarios

Indicator:	2019	Evolution 2050	Equilibrium 2050	Transformation 2050
Primary energy consumption	14.5 Gtoe	17.9 Gtoe	16.8 Gtoe	15.6 Gtoe
Change in the energy intensity of GDP	-1% per year on average since 2000	-1.8% on average for 2020-2050	-2% on average for 2020-2050	-2.2% on average for 2020-2050
Share of fossil fuels in primary energy consumption	81%	63%	48%	31%
Share of modern renewable energy sources in primary energy consumption	2%	18%	28%	39%
Share of electric vehicles in sales of new passenger cars	2%	~ 67%	~ 78%	~ 90%
Share of plastic from recycled feedstocks in the total volume of plastic production	9%	~ 30%	~ 50%	~ 70%
Demand for liquid hydrocarbons	100 mb/d	99 mb/d	74 mb/d	45 mb/d
CCUS capacity	0.04 Gt CO ₂ e	3 Gt CO ₂ e	4.5 Gt CO ₂ e	7.5 Gt CO ₂ e
CO ₂ emissions from land use and forestry	2.9 Gt CO ₂ e	0.6 Gt CO ₂ e	-2.8 Gt CO ₂ e	-6.5 Gt CO ₂ e
CO ₂ emissions from energy sector (including CCUS)	35.1 Gt CO ₂ e	28.1 Gt CO ₂ e	16.6 Gt CO ₂ e	4.6 Gt CO ₂ e
Total greenhouse gas emissions	52.1 Gt CO ₂ e	41.9 Gt CO ₂ e	23.3 Gt CO ₂ e	3.8 Gt CO ₂ e
Median global temperature rise	1.1 °C	2.6 °C	1.8 °C	1.5 °C

Units and abbreviations

Units

Category	Short name	Full name
Energy	toe	Ton of oil equivalent
	Gtoe	Billion tons of oil equivalent
	Mtoe	Million tons of oil equivalent
	boe	Barrel of oil equivalent
	GW	Gigawatt
	MWh	Megawatt-hour
	thousand TWh	Thousand of terawatt-hour
Emissions	t CO ₂ e	Tons of carbon-dioxide equivalent
	Gt CO ₂ e	Billion tons of carbon-dioxide equivalent
	Mt CO ₂ e	Million tons of carbon-dioxide equivalent
	g CO ₂ /km	Grams of carbon-dioxide per kilometer
	kg CO ₂ e	Kilograms of carbon-dioxide equivalent
Oil	bbl	Barrel
	mb/d	Million barrels per day
Gas	bcm	Billion cubic meter
	mmbtu	Million British thermal units
Money unit	\$	US Dollar
Prices	\$/bbl	Dollar per barrel
	\$/mmbtu	Dollar per Million British thermal units
Weight measures	kg	Kilogram
	Mt	Million tons
Area	ha	Hectare

Abbreviations and Acronyms

Abbreviation	Full name
APG	Associated petrol gas
BECCS	Bioenergy with carbon capture and storage
BEV	Battery electric vehicle
CCGT	Combined cycle gas turbine
CCUS	Carbon capture, utilization and storage
DAC	Direct air capture
FCEV	Fuel cell electric vehicle
GDP	Gross domestic product
GHG	Greenhouse gas
ICE	Internal combustion engine
IEA	International Energy Agency
LCOE	Levelized cost of energy
LCOH	Levelized cost of hydrogen
LULUCF	Land Use, Land-Use Change and Forestry
OECD	Organization for Economic Co-operation and Development
PPP	Purchasing power parity
RES	Renewable energy sources
SAF	Sustainable aviation fuel
SPP	Solar power plant
TPP	Thermal power plant
UN	United Nations
WPP	Wind power plant

Forward-looking statements

- ▶ Some statements in this report are forward-looking assumptions. Such statements, in particular, include a description of future events, including the Company's view of the prospects and trends of global energy.
- ▶ All and any information, other than historical facts, is of a predictive nature. Words like «assume», «expect», «suppose», «plan», «intend», «reckon», or similar expressions are intended to indicate forward-looking statements, and shall not be construed as the conclusive way of designating the same.
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