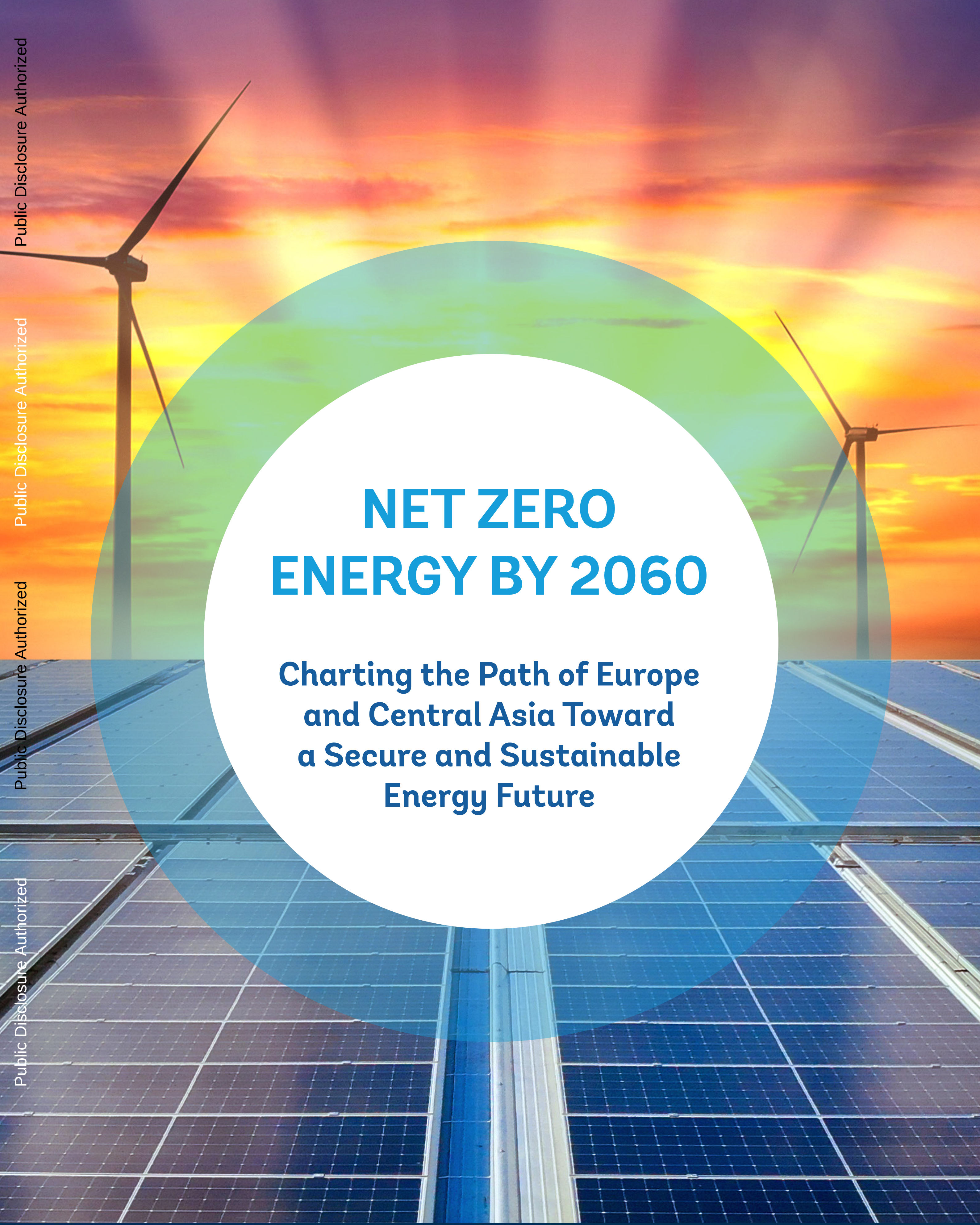
Public Disclosure Authorized
Public Disclosure Authorized
Public Disclosure Authorized



NET ZERO ENERGY BY 2060

Charting the Path of Europe and Central Asia Toward a Secure and Sustainable Energy Future

WORLD BANK GROUP
Energy & Extractives

ESMAP
Energy Sector Management Assistance Program

CONTENTS

Abbreviations and acronyms **6**
Definitions of subregions **7**
Acknowledgments **8**
Executive summary **10**
Country coverage 11
Key findings on short-term energy security 11
Key findings on the energy transition and energy security in the longer term 13
The use of coal, oil, and gas in the region is on the decline through 2060 14
Renewable energy can gradually replace fossil fuels, aided by energy efficiency 14
Greater investment will be needed to achieve the Net Zero 2060 goal 15
Part 1 • Short-term energy security in the region: The crisis is not over **17**
Redefining energy security 17
Gas security 19
Impact on Russia's gas production 22
Impact on countries in the region 23
Gas security in the EU4 and Western Balkan countries 26
Gas security in Central Asia 27
The limits of Türkiye's ability to absorb Russia's surplus gas 28
Oil security: Ongoing shifts 30
Energy security and the energy transition 35
Part 2 • The energy transition: A pathway to a net zero region by 2060 .... **37**
What does it take to decarbonize the region? 42
Transforming the region's gas sector 45
Developing a hydrogen sector 48
Transforming the region's power sector 52
The importance of system flexibility for increasing the role of renewables 55
The combined effect of better demand response and heightened production of green hydrogen 59
The role of regional power exchanges for energy security 59
Transforming energy use in the transport, buildings, and industrial sectors 62
Buildings 63
Transport 65
Industry 66
References **68**
Appendix 1 • Methodology of the World Bank's energy model **72**
Appendix 2 • Decarbonizing district heating **77**
Appendix 3 • Low-carbon fertilizer production in Central Asia **79**
Appendix 4 • Selected liquid fuel pricing subsidies implemented in Europe and Central Asia .. **81**
Appendix 5 • Greenhouse gas emissions in the Europe and Central Asia region in 2020 ..... **82**

List of boxes

Box 2.1 • World Bank Group support of green hydrogen projects in Poland and Chile.................49

Box 2.2 • Delaying the transmission of energy price shocks to consumers: Good or bad?...........57

List of figures

Figure ES.1 • Actual and projected energy-related greenhouse gas emissions by sector in Europe and Central Asia under the Net Zero 2060 scenario, 2019–60 13

Figure ES.2 • Energy sector milestones on the pathway to Net Zero Energy 2060 in Europe and Central Asia region 16

Figure 1.1 • Net imports in Europe and Central Asia region as share of total energy supply, by country and fuel type, 2019 18

Figure 1.2 • Domestic fossil fuel production as percentage of total energy supply (self-sufficiency) in Europe and Central Asia, by country, 2020 19

Figure 1.3 • Pipeline gas flows from the Russian Federation to the European Union, January 2021–June 2023 20

Figure 1.4 • Actual and projected natural gas prices at the Dutch Title Transfer Facility, January 2016–July 2031 21

Figure 1.5 • Actual and projected changes in Russian natural gas production from 2021 levels, 2022–25..22

Figure 1.6 • Gas dependence and gas import dependence in Europe and Central Asia, by country, 2020 23

Figure 1.7 • Underground storage capacity as a share of total consumption in Europe and Central Asia, by subregion, 2021..24

Figure 1.8 • Explicit and implicit natural gas subsidies within Europe and Central Asia as a share of GDP, 2022 25

Figure 1.9 • Natural gas consumption subsidies in selected countries in Europe and Central Asia, 2010–22..26

Figure 1.10 • Projected natural gas balance in Central Asia in the base case and gas union scenarios, 2023–25..28

Figure 1.11 • Actual and projected gas production, consumption, and import dependence in Türkiye, 2019–30..29

Figure 1.12 • Actual and hypothetical Turkish imports of Russian gas, 2019–30............................30

Figure 1.13 • Seaborne crude oil exports by the Russian Federation, by destination, January 2022 and July 2023..31

Figure 1.14 • Exports of Russian oil products, by destination, January 2022 and July 2023...........32

Figure 1.15 • EU imports of Russian crude oil and oil products, January 2019–April 2023 (millions of tonnes)..32

Figure 1.16 • Domestic gasoline prices without taxes in selected countries in Europe and Central Asia, January 2019–July 2023 (€/liter)..34

Figure 1.17 • Global upstream investments in oil and gas, 2010–26 ($ billion) 35

Figure 2.1 • Actual and projected energy-related greenhouse gas emissions by sector in Europe and Central Asia under the reference, partial decarbonization, and Net Zero 2060 scenarios, 2019–60....38

Figure 2.2 • Actual and projected shares of clean and fossil fuels in the primary energy mix in Europe and Central Asia under the reference and Net Zero 2060 scenarios, 2019–60....39

Figure 2.3 • Projected final energy consumption in Europe and Central Asia under the reference and Net Zero 2060 scenarios, by fuel type 40

Figure 2.4 • Energy sector milestones on the pathway to Net Zero Energy 2060 in Europe and Central Asia region 43

Figure 2.5 • Actual and projected global consumption of natural gas under the reference and Net Zero 2060 scenarios, 2019–60 45

Figure 2.6 • Actual and projected global consumption of natural gas under the World Bank's Net Zero 2060 scenario, by sector, 2019–60....46

Figure 2.7 • Actual and projected production, consumption, and trade balance in Europe and Central Asia under the World Bank's Net Zero 2060 scenario, 2019–60....46

Figure 2.8 • Actual and projected net export balance in Europe and Central Asia under the World Bank's Net Zero 2060 scenario, 2019–60 47

Figure 2.9 • Actual and projected consumption of natural gas in Europe and Central Asia under the World Bank's Net Zero 2060 scenario, by sector, 2019–60 47

Figure 2.10 • Actual and projected global consumption of low-carbon hydrogen and share of total final energy consumption under the World Bank's Net Zero 2060 scenario, 2019–60....48

Figure 2.11 • Actual and projected production of low-carbon hydrogen in Europe and Central Asia under the World Bank's Net Zero 2060 scenario, 2019–60 50

Figure 2.12 • Projected production of low-carbon hydrogen from electrolysis and from fossil fuels with carbon capture, usage, and storage in Europe and Central Asia in 2060 under the World Bank's Net Zero 2060 scenario, by subregion....51

Figure 2.13 • Project pipeline in 2023 and projected production of low-carbon hydrogen in 2060 in Europe and Central Asia under the World Bank's Net Zero 2060 scenario, by subregion....51

Figure 2.14 • Projected use of low-carbon hydrogen sector in Europe and Central Asia in 2060 under the World Bank's Net Zero 2060 scenario, by subregion....52

Figure 2.15 • Aggregate trends in electricity generation for ECA countries, 2010–20 53

Figure 2.16 • Share of renewables in energy mix in Europe and Central Asia, by country, 2019 ..54

Figure 2.17 • Actual and projected electricity generation by fuel in Europe and Central Asia under the reference and Net Zero 2060 scenarios, 2025–60....54

Figure 2.18 • Flexible electricity system resources and the role of demand aggregators 59

Figure 2.19 • Actual and projected total final energy consumption in Europe and Central Asia (excluding Russia and Belarus) under the reference and Net Zero 2060 scenarios, by sector, 2021–60....62

Figure 2.20 • Actual and projected total final energy consumption by buildings in Europe and Central Asia (excluding Russia and Belarus) under the reference and Net Zero 2060 scenarios, by fuel type, 2021–60 63

Figure 2.21 • Actual and projected number of residential heat pumps in Europe and Central Asia under the World Bank's Net Zero 2060 scenario, by subregion, 2019–60 64

Figure 2.22 • Actual and projected uptake of insulation measures and heat pumps in Europe and Central Asia under the reference and Net Zero 2060 scenarios, 2019–60 64

Figure 2.23 • Actual and projected total final energy consumption in the transport sector in Europe and Central Asia (excluding Russia and Belarus) under the reference and Net Zero 2060 scenarios, 2021–60 65

Figure 2.24 • Actual and projected number of electric vehicles in Europe and Central Asia under the World Bank's Net Zero 2060 scenario, by vehicle type, million vehicles, 2019–60 66

Figure 2.25 • Actual and projected final energy consumption of industry sector in Europe and Central Asia under the reference and Net Zero 2060 scenarios, by fuel type, 2021–60 67

Figure A1.1 • Structure of the KINESYS model 72

Figure A3.1 • Levelized cost of green (solar-powered), blue, and gray ammonia production in Central Asia under the Net Zero 2060 scenario 80

List of tables

Table 2.1 • Projected investment needs in Europe and Central Asia in the reference and Net Zero 2060 scenarios, by sector 44

Table B2.2.1 • Ability to mitigate transmission of short-term price shocks to consumers in Europe and Central Asia, by country 58

Table 2.2 • Day-ahead, intra-day, and futures markets of power exchanges in Europe and Central Asia, by country 61

Table A1.1 • Data sources for and inputs into the model 74

Table A4.1 • Selected liquid fuel pricing measures implemented in Europe and Central Asia in 2022, by country 81

Table A5.1 • Global greenhouse emissions and emissions within Europe and Central Asia, by country, 2020 82

ABBREVIATIONS AND ACRONYMS

b/d	barrels per day
bcm	billion cubic meters
CCDR	Country Climate and Development Report
CCS	carbon capture and storage
CCUS	carbon capture, usage, and storage
CO_2	carbon dioxide
DH	district heating
e-mobility	electric mobility
ECA	Eastern Europe and Central Asia
ESMAP	Energy Sector Management Assistance Program
EU	European Union
EU4	Bulgaria, Croatia, Poland, Romania
EV	electric vehicle
IEA	International Energy Agency
IEA-ETSAP	International Energy Agency's Energy Technology Systems Analysis Program
GDP	gross domestic product
GIIGNL	International Group of Liquefied Natural Gas Importers
GIS	geographic information system
GHG	greenhouse gas
GW	gigawatt
IIASA GLOBIOM	International Institute for Applied Systems Analysis, Global Biosphere Management Model
IFC	International Finance Corporation
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
KINESYS	Knowledge-based Investigation of Energy System Scenarios
LNG	liquefied natural gas
LPG	liquefied petroleum gas
MW	megawatt
MWh	megawatt hour
Mt	megatonne
t	tonne
tCO_2e	tonnes of carbon dioxide equivalent
SSP	Shared Socioeconomic Pathway
TIMES	The Integrated MARKAL-EFOM System of IEA-ETSAP
TFC	total final energy consumption
TPES	total primary energy supply
TTF	Title Transfer Facility
TWh	terawatt hour
UN	United Nations
US EPA	United States Environmental Protection Agency
VAT	value added tax

All currency is in United States dollars unless otherwise indicated.

Unless otherwise noted, the graphs and charts presented herein represent results of an original model conceived by the authors, and historical data are sourced from the International Energy Agency's 2019 and 2020 Energy Balances.

DEFINITIONS OF SUBREGIONS

ECA consists of the following subregions and countries:

Subregion	Country or countries
Central Asia	Kazakhstan, Kyrgyz Republic, Tajikistan, Turkmenistan, Uzbekistan
Caucasus	Armenia, Azerbaijan, Georgia
EU4	Bulgaria, Croatia, Poland, Romania
Russia, Belarus	Russia, Belarus
Türkiye	Türkiye
Ukraine, Moldova	Ukraine, Moldova
Western Balkans	Albania, Bosnia and Herzegovina, Kosovo, North Macedonia, Montenegro, Serbia

ACKNOWLEDGMENTS

The World Bank ECA Energy Futures team worked under the leadership of Anna Bjerde, Antonella Bassani, Carolina Sanchez-Paramo, Charles Joseph Cormier, Sudeshna Ghosh Banerjee, Stephanie Gil, and Ivailo Izvorski. The World Bank ECA Energy Futures core team included Task Team Leader Szilvia Doczi and co-authors Akos Losz (parts 1 and 2); Amit Kanudia (appendix 1, energy system model developer); Armin Mayer (part 2); Bobur Khodjaev, Humphrey Fellow (appendix 3); Elcin Akcura (part 1 and appendix 4); Peter Toth (part 2); Raimund Malischek (parts 1 and 2 and appendix 1); Rocco De Miglio (parts 1 and 2 and appendix 1); and Tarek Keskes (part 2 and appendix 5). Unless otherwise noted, the projected years in tables, graphs, and charts presented herein represent results of an original model conceived by the authors, while the historical data are sourced from the International Energy Agency's 2019 and 2020 Energy Balances.

The report benefited from World Bank peer reviewer comments received from Alexander Huurdeman, Ani Balabanyan, Maria Vagliasindi, and Rafael De Sa Ferreira and inputs and comments from World Bank subject matter experts including Zuzana Dobrotkova (renewables), Jas Singh (energy efficiency and sustainable heating), David Groves and Craig Meisner (climate), Dolf Jean Gielen (hydrogen and industry), Priyank Lathwal (hydrogen), Adam Brown (renewables), Claire Nicholas (power sector), Masami Kojima (oil and gas), Shomik Raj Mehndiratta (transport), Karla Gonzalez Carvajal (transport), Eduardo Espitia Echeverria (transport), Joao Rampini (transport), and Nicole Frost, Nick Keyes, Aaron Korenewsky, Zarina Nurmukhambetova (communications). World Bank energy specialist colleagues Silvia Martinez Romero, Manuel Berlengiero, Stephan Claude Frederic Garnier, Claire Nicolas, Joern Huenteler, Katharina Gassner, Claudio Protano, Maksud Safarov, Irina Voitekhovitch, Almudena Mateos Merino, Chris Trimble, Yun Wu, Tamara Babayan, Mariano Gonzalez Serrano, Luiz Gabriel Sucrmont Rodrigues Simoes, Hazuki Terada, and Celia Rui provided regional and country insights on hydro and nuclear expansion, electricity, and gas cross-border transmission capacity expansion pathways, and energy efficiency potentials.

The ECA Energy Futures report benefited from invaluable insights and peer review comments from its Advisory Committee members: Sauleh Siddiqui, Chief Modeler of the U.S. Energy Information Administration; Tim Gould, Chief Economist of the International Energy Agency; Tatiana Mitrova, Research Fellow at Columbia University's Center on Global Energy Policy; and Laszlo Varro, Vice President, Global Business Environment at Shell. The report benefited from comments, interviews, inputs, and insights from Araceli Fernandez Pales, Apostolos Petropoulos, Brent Wanner, Craig Hart, Christophe McGlade, Jerome Hilaire, Jonathan Coppel, Paul Hugues, Peter Zeniewski, Simon Bennett, Stephanie Bouckaert, Uwe Remme, and Zoe Hungerford (International Energy Agency); Luis Janeiro (International Renewable Energy Agency); Douglas Nordham (Future Energy Leader, GHD); Francisco Venturini; and Daniele Andreoli (Enel X).

The team would like to thank Demetrios Papathanasiou (Global Director, EEX), Chandrasekar Govindarajalu (Practice Manager, ESMAP), and Gabriela Elizondo Azuela (Practice Manager, Latin America and Caribbean; former Practice Manager, ESMAP) for their managerial guidance and invaluable support.

Steven B. Kennedy edited the report.
Adil Bekishev designed the report.

The Energy Sector Management Assistance Program (ESMAP) is a partnership between the World Bank and over 20 partners to help low- and middle-income countries reduce poverty and boost growth through sustainable energy solutions. ESMAP's analytical and advisory services are fully integrated within the World Bank's country financing and policy dialogue in the energy sector. Through the World Bank, ESMAP works to accelerate the energy transition required to achieve Sustainable Development Goal 7 (SDG7) to ensure access to affordable, reliable, sustainable, and modern energy for all. It helps to shape WB strategies and programs to achieve the WB Climate Change Action Plan targets.

Until one is committed there is hesitancy, the chances to draw back, always ineffectiveness. Concerning all acts of initiative (and creation), there is one elementary truth, the ignorance of which kills countless ideas and splendid plans: that the movement one definitely commits oneself, then providence moves, too.
A whole stream of events issues from the decision, raising in one's favor all manner of unforeseen incidents, meetings and material assistance, which no man could have dreamt would have come his way.

by W.H. Murray during his Himalayan expedition

Executive Summary

Since February 2022, geopolitical events have made clear Europe's need to diversify its energy sources and avoid excessive dependence on fossil fuel imports. The drop in Russian natural gas flows to Europe in 2022 marked the single largest supply shock in the history of global gas markets. It caused a significant increase in prices of electricity and heating services for consumers across the continent. With Europe's high reliance on imported natural gas, reestablishing energy security is a paramount objective. But how security can be achieved is subject to many uncertainties. Although Central Asia is not as dependent on gas imports as other parts of the World Bank's Europe and Central Asia (ECA) region, it has not been spared an energy crisis. Chronic underinvestment and the harshest winter conditions in decades resulted in significant blackouts in power and heating during the winter of 2022/23.

This report analyzes the implications of the 2022/2023 energy crises over the short and long term, observing possible energy scenarios through 2060 in the Bank's ECA region and examining three key questions:

- What is the state of energy security in ECA in the wake of recent geopolitical events?
- What will it take to decarbonize the ECA energy system?
- What are the main uncertainties?

Even before Russia's invasion of Ukraine, supplies of Russian gas to Europe were becoming increasingly unreliable (EC 2022c, IEA 2022g). Since 2022, the European Union (EU) has implemented a series of measures to reduce dependency on imports of fossil fuels and accelerate the development of alternate sources of energy through the REPowerEU plan. Following the EU model, several ECA countries began their own efforts to promote energy security and diversify energy sources.

The European Union's efforts to scale up renewables and decouple from imports of Russian gas are bearing fruit. The International Energy Agency estimated in December 2022 that the EU gas supply gap for 2023 had already been halved—to less than 30 billion cubic meters (bcm)—through energy-saving measures, infrastructure investments, and the accelerated deployment of renewables and heat pumps. Since then, the gap has continued to narrow. An ongoing commitment to energy efficiency improvements, increased deployment of renewables, diversification of gas imports, and gas saving measures brought gas stocks to a comfortable level by December 2023. The European Union's success sets a good example for the ECA region. However, energy intensive industries have suffered throughout the region.

The energy crisis is not over. Measures to help consumers cope with high energy prices have not been fully scaled back, leading to higher subsidies, and uncertainties remain regarding the long-term supply of natural gas. However, a severe gas shortage is now confined to worst-case scenarios.

The World Bank has developed a model to project an optimal least-cost pathway for ECA to achieve a net zero energy target by 2060. Together, the 23 countries included in the model produce almost a tenth of global greenhouse gas emissions. The report takes into account the profound impact the war in Ukraine has had on energy security by representing energy trade flows on the basis of gas pipeline flows and capacities as of May 2023 and under a stress test. This novel analysis delivers insights not covered by previous works, focused mainly on the European Union.

The report is organized as follows. Part 1 of this report reviews the short-term energy security outlook. Part 2 presents the vision of the Net Zero 2060 scenario for the region, followed by detailed, model-based insights into what it will take to decarbonize the region.

This report is the first in a series of Bank reports on the energy transition in ECA, and thus it is limited in scope and length. The next two papers will (i) detail the barriers to the scale-up of renewables in ECA and provide policy advice for addressing these barriers and (ii) investigate the macroeconomic aspects of the energy transition by presenting economic growth opportunities, including policy, market, and regulatory options with case studies, and the relevance of institutional capacity and governance. Macroeconomic sensitivities and iterations are not reflected in the results presented in this report, with the exception of the World Bank's country-level GDP projections and UN population growth projections, as drivers of the demand for various energy services. Further work on macroeconomic, fiscal, financing, and climate (damages and adaptation) aspects of the energy transition can expand and enrich the results presented in this report.

COUNTRY COVERAGE

This report focuses on the ECA region, specifically those countries in the region with which the World Bank works most closely. Countries in the region make up 6.3 percent of the world's population, 7 percent of world GDP (2019), nearly 10 percent of world energy emissions, and 16 percent of fossil fuel extractions. The 23 countries are divided into seven subregions: Central Asia, the Caucasus, the EU4, Russia and Belarus, Türkiye, Ukraine and Moldova, and the Western Balkans.[1] The insights reported are designed to help stakeholders prioritize strategies and policies to transition to clean and secure energy systems. The report also highlights immediate and longer-term investment opportunities arising from the energy transition in the region.

KEY FINDINGS ON SHORT-TERM ENERGY SECURITY

How likely are shortages of natural gas and electricity in the region over the next few years? Overall, the region's energy system is vulnerable to supply shocks as well as to seasonal demand shocks arising from summer droughts and heat waves and winter cold spells. The Western Balkans and Central Asia are especially vulnerable to potential natural gas shortages, because of their infrastructure deficits and low levels of cross-border trade.

Limited availability of underground natural gas storage exacerbates exposure to gas supply shocks in parts of the ECA region. The Western Balkans and EU4 countries, where storage cover is 12 percent and 19 percent of consumption, respectively, are especially vulnerable (the average for the European Union is 25 percent, figure 1.7). These vulnerabilities make countries dependent on timely imports of gas supplies (notably via pipelines from neighboring countries), especially during the peak winter period. Türkiye and Central Asia have even lower storage cover—7 percent and 8 percent of consumption, respectively. Countries in Central Asia suffered gas shortages and blackouts in recent winters. Ukraine has vast underground storage capacity; it could become a valuable energy security asset for the broader European market, including for the European countries within the ECA region.

Natural gas and coal subsidies can undermine energy security and exacerbate energy crises in parts of the ECA region, while also undermining decarbonization efforts. High subsidies are especially problematic for net importers of natural gas (such as Ukraine), for Central Asia and other areas in which large seasonal swings in demand coincide with insufficient system flexibility and storage capacity, and for countries in which power generation and heating are fueled almost exclusively by natural gas

---

1 The countries of the Central Asia subregion are Kazakhstan, the Kyrgyz Republic, Tajikistan, Turkmenistan, and Uzbekistan. The Caucasus subregion is made up of Armenia, Azerbaijan, and Georgia. The EU4 includes Bulgaria, Croatia, Poland, and Romania. Türkiye is its own subregion. The Ukraine subregion includes Moldova. The Western Balkans are made up of Albania, Bosnia and Herzegovina, Kosovo, North Macedonia, Montenegro, and Serbia.

(such as Azerbaijan and Uzbekistan).[2] Subsidy and tariff reforms require long-term planning and a safety net to protect the vulnerable population, but they can be well aligned with decarbonization efforts. For example, investments in energy efficiency can offset the effects of subsidy removal by lowering households' energy consumption while improving heating comfort levels and reducing underheating prevalent in the Western Balkans and Central Asia.

In the short term, Central Asia faces a tightening gas supply balance and some difficult choices. Central Asia has been a large net exporter of gas, notably to China. Rapidly growing demand within the entire subregion, combined with stagnating production (especially in Kazakhstan and Uzbekistan), limit the ability to meet export commitments to China and peak winter demand at home simultaneously. Russia's proposed gas union with Kazakhstan and Uzbekistan could improve Central Asia's natural gas balance, although the poor state of pipeline infrastructure (IEA 2016) poses uncertainties. Improving regional gas trade in Central Asia and increasing gas imports from Turkmenistan could be also used to replace coal in Kazakhstan, fill the emerging supply gap in Uzbekistan, and meet growing demand across Central Asia.

The reduction of pipeline gas flows between Russia and the European Union and the EU's subsequent efforts to cut its dependence on fossil fuel imports are likely to affect Russia's natural gas production. Production contracted in 2022, as pipeline exports to the European Union were progressively reduced. Because Russia's near-term options to redirect gas from its traditional European markets to Asia are limited, Russian domestic production in 2025 could be 150–160 bcm lower than it was in 2021 and 200 bcm lower than earlier projections for 2025. This loss of supply is sizable, comparable in volume to the total gas consumption of the entire ECA region excluding Russia (270 bcm) and roughly equivalent to the combined 2021 exports of liquefied natural gas (LNG) from Qatar and the United States (200 bcm), two of the world's three largest producers of LNG.

In a stress test scenario in which Russian gas is fully discontinued to Europe (including the EU4, the Western Balkans, Ukraine, and Moldova) localized gas supply crises could arise, especially during the next few winters.

Russian pipeline gas flows to Türkiye have continued uninterrupted throughout the energy crisis, but Türkiye's ability to absorb significantly more gas from Russia is limited in the medium term.

Decarbonization in the medium term through renewables, energy efficiency and a shift away from natural gas in heating and power generation could reduce import dependency in the countries of the region that are net importers.

2 Energy subsidies reach up to 2–19 percent of GDP in ECA countries, according to the IEA 2021 energy consumption subsidy database. (IEA. 2022b.)

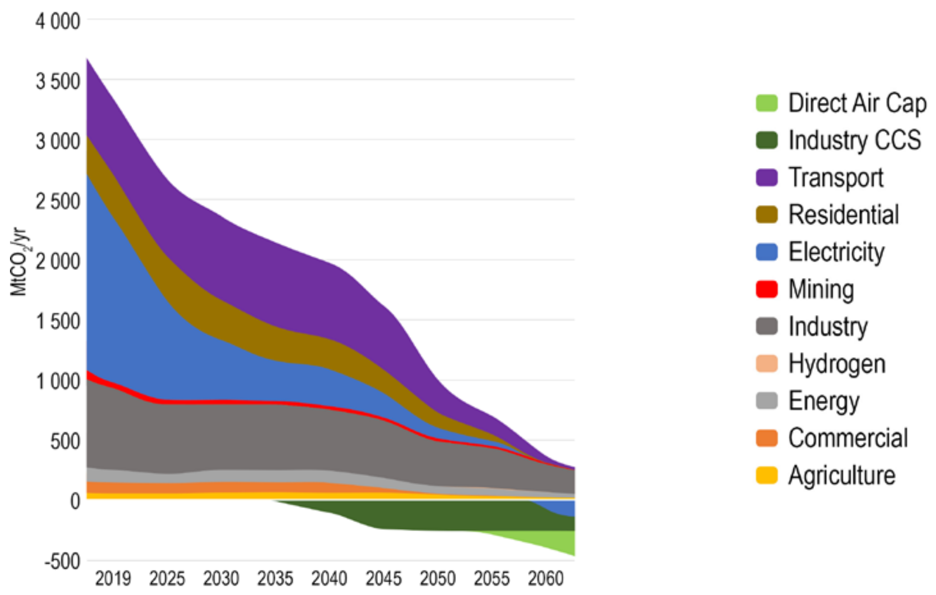
KEY FINDINGS ON THE ENERGY TRANSITION AND ENERGY SECURITY IN THE LONGER TERM

Fourteen of the region's 23 countries have not yet set net zero targets; this report provides a vision and a path for them to do so. Nine ECA countries have already established net zero economy targets; five of them (Armenia, Bulgaria, Croatia, the Kyrgyz Republic, and Romania) have chosen a 2050 target for achieving a net zero economy. Türkiye aims to reach the goal by 2053. Kazakhstan, Russia, and Ukraine have set a more distant target of 2060.

Despite some progress, with current ambitions, the region cannot reach net zero emissions in time to help limit the global temperature increase to the 1.5°C target called for in the 2015 Paris Agreement on climate change (UNFCCC 2015).

The Net Zero 2060 scenario presents an ambitious but possible least-cost pathway for ECA to decarbonize its energy system by 2060 while helping to maintain a global temperature rise of less than 2°C (figure ES.1). According to the model results, to achieve carbon neutrality in 2060, the power systems of the 23 ECA countries must be net zero by 2040; carbon neutrality of commercial buildings must be achieved by 2050; and carbon neutrality of residential buildings must be achieved by 2055. Decarbonization of transport and industry is the most challenging; even in 2060 these sectors will rely on carbon removal technologies for their decarbonization.

Figure ES.1 • Actual and projected energy-related greenhouse gas emissions by sector in Europe and Central Asia under the Net Zero 2060 scenario, 2019–60



ECA's energy transition requires that both supply and demand move to clean technologies. In the next 10 years ECA countries can make immense progress toward net zero power, heating, and transport using existing new technologies, the most important of which are either already mature and cost-effective (even relative to fossil fuels) or are expected to become so in ECA in the next 10 years. These include, on the supply side, the renewables needed for the power sector's decarbonization and, on the demand side, EVs for transport and heat pumps for buildings. These new technologies offer no-regret investments in decarbonization. Beyond 2035, however, uncertainties are higher.

Decarbonization can bring the following benefits beyond climate and pollution benefits: greater energy security, greater competitiveness, stable or lower energy bills, and job creation in new green markets.

The use of coal, oil, and gas in the region is on the decline through 2060

Coal is the largest source of fossil fuel emissions in the region, representing 42 percent of all emissions in ECA (excluding Russia). Without action, it is set to provide 25–30 percent of the region's energy (excluding Russia) for decades. In the least-cost regional decarbonization pathway reported here, 90 percent of existing coal capacities are phased out in the 21 ECA countries by 2030. This is equivalent to 31 gigawatts (GW) of coal assets being retired early by 2030, ahead of their average 40 years' useful life. Without a swift phasing down of coal use, ECA will not be able to decarbonize.

Phasing down coal is the most effective way to reach climate objectives. It also reduces the economic costs of pollution, which typically outweigh the costs of stranded assets presented in ECA CCDRs.

Gas consumption may already have peaked (or is about to peak) in ECA, but gas will nevertheless play an essential role in the region for at least another two decades. Natural gas declines from over 40 percent of the primary energy supply in 2019 to 16 percent in 2060 in the Net Zero 2060 scenario. It is used with CCS (carbon capture storage) for balancing purposes in power and as fuel and feedstock in industry through 2060 and beyond, even amid a transition to net zero emissions. Under the Net Zero 2060 scenario, gas production in the region is projected to fall more than consumption, eroding the region's traditional gas surplus by 2060. The declining production of gas in the region is driven by Russia's permanent loss of its European export market—and with it, more than 200 bcm of gas supply potential over time. In Central Asia, production drops by half between 2019 and 2060, in the absence of new discoveries.

Oil use peaks by 2035 in the Net Zero 2060 scenario. Oil use in transport drops to a 9 percent share of transport fuels by 2060, down from 90 percent in 2019. Reliance on oil for aviation, trucking, and shipping persists, as these subsectors are the hardest to abate, even with intense application of clean transport technologies (biofuels, hydrogen, ammonia, methanol, synthetic fuels, and EVs) and a shift to more public transport.

Renewable energy can gradually replace fossil fuels, aided by energy efficiency

Increasingly competitive renewable energy generation enables countries to increase the share of domestic energy resources and reduce their dependence on fossil fuel imports.

The renewable sources of energy (solar, wind, hydro, and bioenergy including biomass and biofuels) that are replacing coal are already cost-effective in most ECA countries or will become so in the next 10 years. In the Net Zero 2060 pathway, solar-based power generation grows five-fold by 2030, and wind-based power generation nearly doubles. The use of bioenergy doubles by 2050. Another clean energy source also plays an important role: Nuclear power generation doubles by 2035.

The share of electricity in the energy mix almost triples by 2060 (from 16 percent in 2019 to 47 percent) as heating/cooling, transport, and certain industrial processes are increasingly electrified.

On the demand side, energy efficiency, technology advances, and behavioral change have the potential to cut total final energy consumption by 28 percent by 2060 compared with the reference case. High growth in the use of electric vehicles (EVs) from 2035 drives the energy efficiency and electrification of transport in the Net Zero 2060 scenario, creating a market for over 200 million EVs by 2060 (mostly cars, but also millions of light trucks, heavy trucks, and buses), in combination with a shift to more public transport and new fuel efficiency standards.

Energy efficiency already saves 15 percent of projected residential buildings' energy demand in the reference scenario, in which it is included because it is cost-effective without emission constraints and therefore represents a no-regrets investment for every country. Energy efficiency keeps energy consumption in check amid rising demand. It also stabilizes energy bills during the energy transition by lowering household consumption by volume.

Electrification and heat pumps, alongside bioenergy, are a cornerstone of decarbonization in the region's buildings. Strong uptake of heat pumps is expected in the Net Zero scenario from 2035 (in the absence of carbon pricing or incentives), with a possibility of reaching 100 million household units by 2060.

Enabling policies and measures on the demand side are a prerequisite for achieving the energy savings and emissions reductions outlined in the Net Zero 2060 scenario. Examples include national programs for policies, financing, incentives, and outreach, tightening energy performance standards for buildings and equipment and phasing out fossil technologies, such as internal combustion engines, and coal and gas boilers for residential heating. Combined with targeted compensation mechanisms for vulnerable populations, these kinds of measures enable the deployment, at scale, of key efficiency technologies.

The region's pipeline of clean hydrogen projects under construction or in various stages of planning (at 3.8 megatonnes [Mt]) represents only a small fraction of the capacity needed to meet net zero goals (18 Mt by 2050 and 44 Mt by 2060). More than half of the region's planned capacity (2 Mt) is attributable to a single megaproject in Kazakhstan.[3]

For ECA to reach net zero energy by 2060, less cost-competitive and less-mature technologies (including low-carbon hydrogen and carbon removal) must develop further and offer higher degrees of certainty beyond 2035. Clean hydrogen could account for 10–13 percent of final consumption in ECA by 2060, depending on the development of end-use markets, especially transport. Unless carbon prices rise substantially, however, low-carbon hydrogen production in the region is likely to remain uneconomic without subsidies for at least another two decades. Clean hydrogen production in 2060 is dominated by renewable (green) hydrogen in the Net Zero 2060 pathway.

Greater investment will be needed to achieve the Net Zero 2060 goal

The total regional investment needed between 2023 and 2060 to achieve the Net Zero 2060 goal amounts to $4.7 trillion (3.9 percent of regional GDP). The additional amount needed compared with the reference scenario is $872 billion (0.7 percent of GDP). This estimate is at the lower end of the range presented in *Insights from World Bank Country Climate and Development Reports Covering 42 Economies* (World Bank 2023a).[4] The power sector accounts for the largest share of the additional investment needed: The Net Zero 2060 investments for the sector ($934 billion) are $535 billion higher than in the reference scenario. Growing cross-border gas and electricity trade and the decarbonization of industry add more than $180 billion to the Net Zero pathway's investment needs.

Under both the reference and Net Zero 2060 scenarios, more than $1.2 trillion must be invested in improving residential buildings and appliances, including heat pumps. However, the same heating and cooling comfort levels are achieved at much lower operating costs in the Net Zero scenario, as these investments reduce energy demand compared with the reference scenario.

The transport sector requires the greatest investment in both scenarios—more than $1.4 trillion.

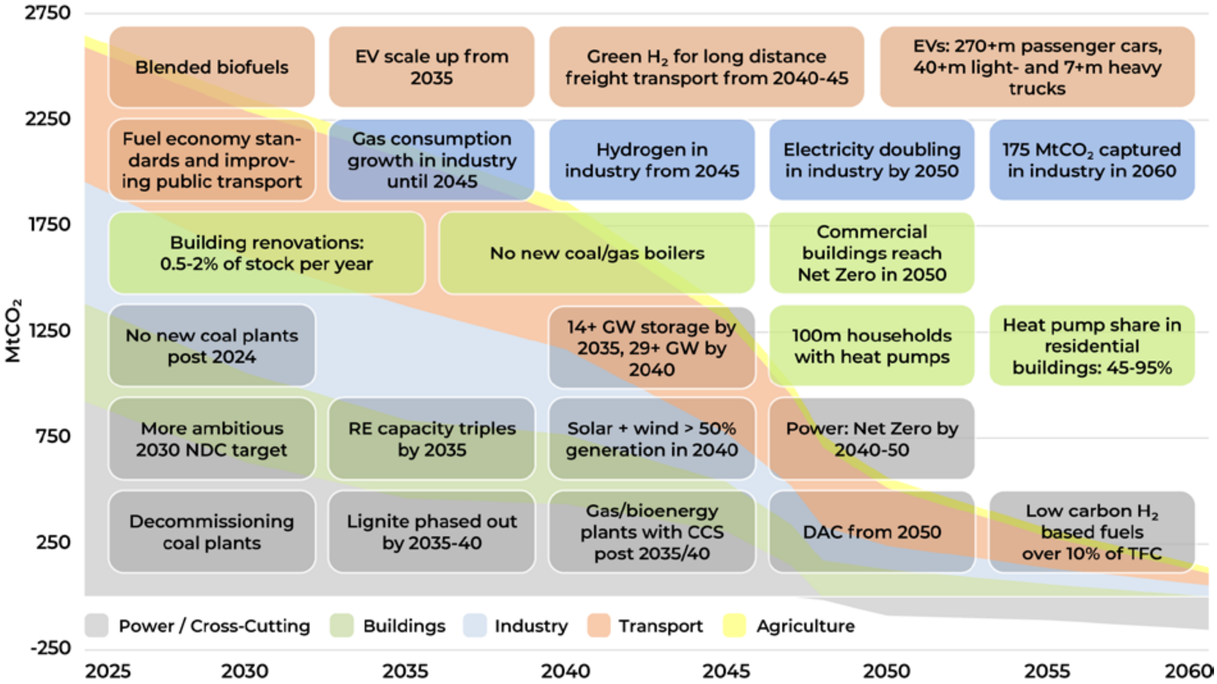
Without new targeted policies and measures, such as the ones illustrated in figure ES.2 and in Part 2 of this report, only a fraction of the required investment in low-carbon technology is likely to be made, resulting in a missed opportunity to protect households, services, and industry.

---

3 Clean (or low-carbon) hydrogen-based fuels come in two forms. Blue hydrogen is produced from fossil fuels coupled with carbon dioxide capture and storage. Green (or renewable) hydrogen is produced by water electrolysis using renewable electricity. Low-carbon hydrogen-based fuels also include hydrogen derivatives such as ammonia and methanol; they are referred to as hydrogen in this report.

4 In the synthesis report (World Bank 2023a), the additional investment need for the energy transition ranged from 1 percent of GDP for upper-middle-income countries to 10 percent for lower-income countries.

Figure ES.2 • Energy sector milestones on the pathway to Net Zero Energy 2060 in Europe and Central Asia region



PART 1 • SHORT-TERM ENERGY SECURITY IN THE REGION: THE CRISIS IS NOT OVER

Fossil fuel supply, import dependency, and affordability affect short-term energy security in Europe and Central Asia (ECA). Fossil fuels (natural gas, oil, and coal) still make up more than 80 percent of the region's energy mix. Net import dependency is very high, at half or more of total energy supply in nine countries. Energy security is not limited to fossil fuels. It is closely linked to energy efficiency and renewable energy at scale, as well as climate change and the energy transition. Because natural gas and electricity prices in the region are likely to remain high and volatile beyond 2023–24, investments in decarbonization—including, for instance, retrofitting buildings for energy efficiency, implementing industrial energy efficiency improvements, and scaling up renewables—are essential to protect economies in the short term and ensure energy security.[5]

REDEFINING ENERGY SECURITY

Energy security is a balancing act between meeting current energy needs and ensuring future access to resources. The term generally refers to the uninterrupted availability of energy supplies at an affordable price, with respect for environmental concerns (IEA 2022d). Short-term energy security focuses on the ability of the energy system to react promptly to sudden changes in the balance of supply and demand. Long-term energy security depends on making timely investments to supply energy in line with economic developments and environmental needs. In view of the ongoing energy crisis, geopolitical developments, and macroeconomic environment, importing countries in ECA have not been able to divert their attention from short-term energy security, affordability, and the ability of their energy systems to react promptly to sudden changes in the supply-demand balance.

Thinking about energy security in the region is changing as a result of several factors, including (i) a sharper focus on the transition to clean and renewable energy; (ii) stresses and strains in the geopolitical context; and (iii) macroeconomic changes, particularly higher borrowing costs. The energy transition will greatly expand electrification, placing at center stage the variability of both supply and demand, the resilience of clean energy supply chains, and economic competitiveness, even as traditional oil and gas security issues persist. Russia's actions in Ukraine have exacerbated energy security concerns, reoriented trade flows, imposed longer and costlier transport routes for some imported fuels, and sapped trust in natural gas supply among exporters and importers.

The countries of the region are not equally exposed to energy security challenges. Challenges differ by country, by fuel, and over time. Security concerns range from sub-seconds in electricity markets to the balancing of seasonal and yearly energy supply and demand to investment decisions about capital-intensive infrastructure investments with decades long impact.

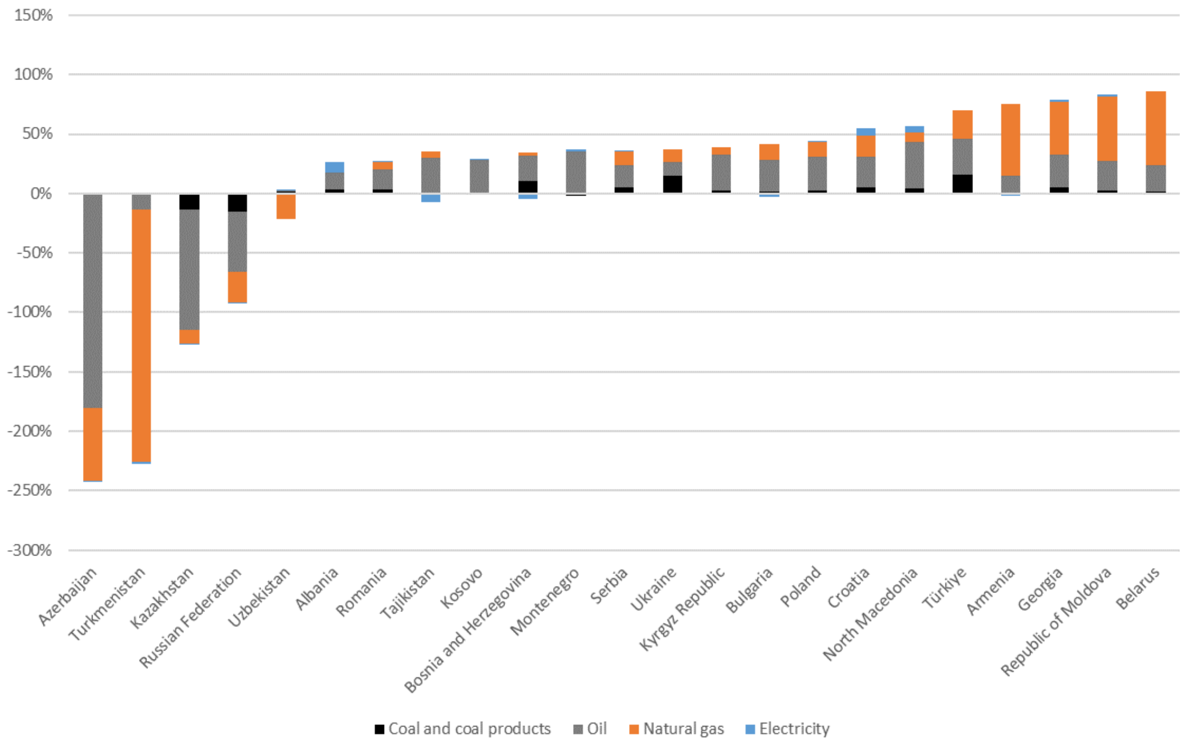
Fossil fuels still dominate the region's energy mix. Renewables play only a limited role. Hydropower is an important exception; it is the main source of electricity in Albania, Georgia, Tajikistan, and the Kyrgyz Republic and plays an important role in several other countries in the region. Among fossil fuels, coal dominates in Bosnia and Herzegovina, Bulgaria, Kazakhstan, Kosovo, Poland, Serbia, and Ukraine; oil in Albania, Croatia, Kyrgyz Republic, Montenegro, North Macedonia, Romania, and Turkiye; and natural gas in Armenia, Azerbaijan, Belarus, Georgia, Moldova, Russian Federation, Turkmenistan, and Uzbekistan.

Reliance on undiversified fossil fuel imports remains the major energy security consideration in ECA countries. Net import shares of natural gas in total energy supply are 55 percent in Armenia and 60 percent in Moldova. Import shares of crude oil are 26 percent in Romania and 38 percent in Bulgaria. Net import dependency is greater than 50 percent of total energy supply in nine ECA countries (figure 1.1).

---

5 Unless otherwise noted, the graphs and charts in this part of the report are the authors' original work drawn from the model results.

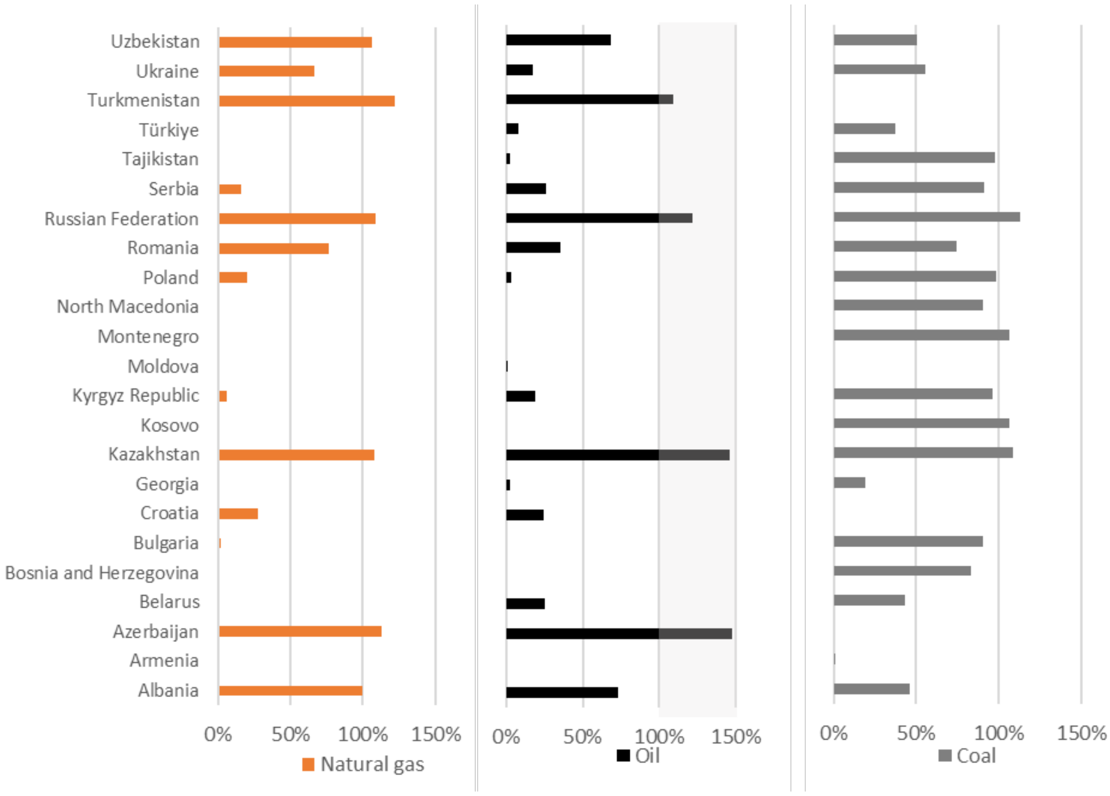
Figure 1.1 • Net imports in Europe and Central Asia region as share of total energy supply, by country and fuel type, 2019



Source: IEA 2022f.

Fossil fuel producers and exporters—including Russia, Kazakhstan, and Azerbaijan—are largely self-sufficient with respect to fossil fuels. Many ECA countries, including Tajikistan, Russia, Poland, Montenegro, Kosovo, and Kazakhstan—are 100 percent self-sufficient in coal. Self-sufficiency in coal is more widespread than self-sufficiency in oil or natural gas (figure 1.2). The ECA region's share of global fossil energy extraction (16 percent) is much larger than its share of global emissions (9.9 percent), reflecting the importance of exports. Russia leads the region in fossil energy extraction, at 74 percent of the regional total. Its 56 exajoules of fossil fuels in 2020 represented 11.8 percent of global emissions. In past decades, several ECA countries (e.g., Tajikistan and the Kyrgyz Republic) significantly increased their fossil fuel extraction rates.

Figure 1.2 • Domestic fossil fuel production as percentage of total energy supply (self-sufficiency) in Europe and Central Asia, by country, 2020



Source: IEA 2022f.

GAS SECURITY

Natural gas is the backbone of the region's energy system, constituting 46 percent of the primary energy supply in ECA as a whole (34 percent when excluding Russia).[6] This figure is considerably higher than the 24 percent figure for the European Union. Gas is expected to retain its prominent role in the region's energy mix for at least another two decades. It will continue to be used for balancing purposes in power and as feedstock in industry through 2060 and beyond, even amidst a transition to net zero emissions.

Gas can contribute to the region's decarbonization efforts. Specifically, it can do so if it is used to replace coal, if wasteful energy use is reduced, if life-cycle greenhouse gas emissions are mitigated, and if its use is combined with carbon capture, utilization, and storage (including for power generation and blue hydrogen production). However, the region's reliance on gas over the medium-term poses challenges for energy security. The gas supply–demand balance is tightening as production comes under pressure in Central Asia in particular.

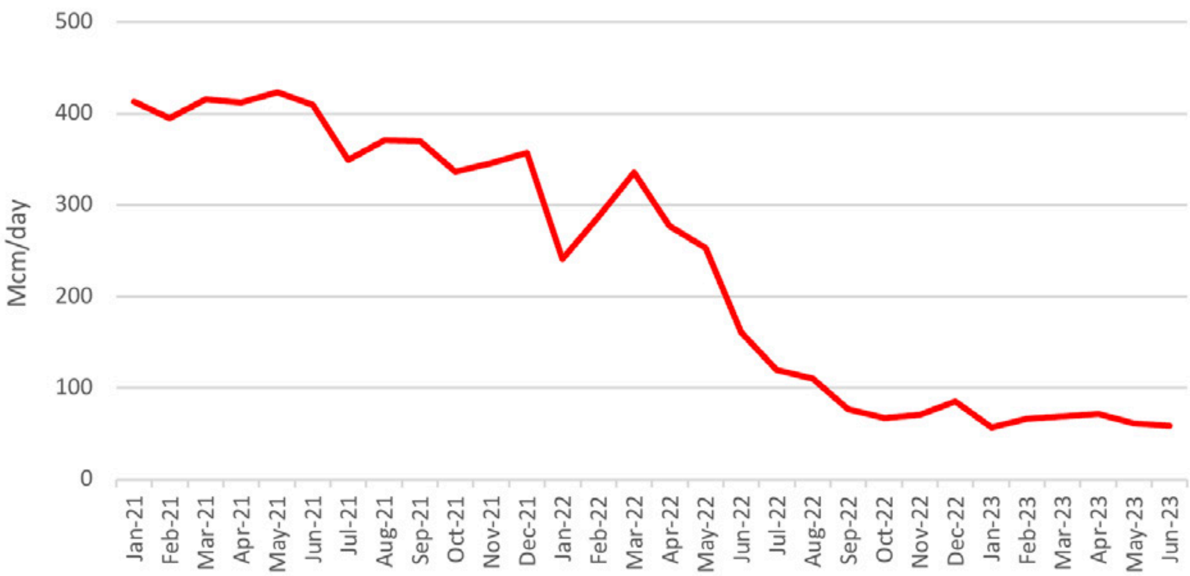
The sharp cutback in pipeline flows of Russian gas to Europe in 2022 constitutes the single biggest supply shock in the history of global gas markets. In 2021, Russia's state-controlled export monopoly, Gazprom, piped 140 bcm of gas to customers in the European Union. In 2022, those imports dropped to just over 60 bcm. In 2023, Russian pipeline gas deliveries to the EU were on track to drop to 20–25 bcm, less

---

6 This first part of the analysis was finalized in April 2023, the first part of the report was finalized in October 2023. Data points, market developments, and policy measures after these dates are not reflected in the analysis. Figures are based on 2021 data extracted from the 2022 edition of the International Energy Agency's extended world energy balances database.

than a sixth of pre-2022 levels (figure 1.3). In the current geopolitical context, further reductions of Russian pipeline gas exports to the European Union cannot be ruled out.

Figure 1.3 • Pipeline gas flows from the Russian Federation to the European Union, January 2021–June 2023



Source: ENTSOG 2023.

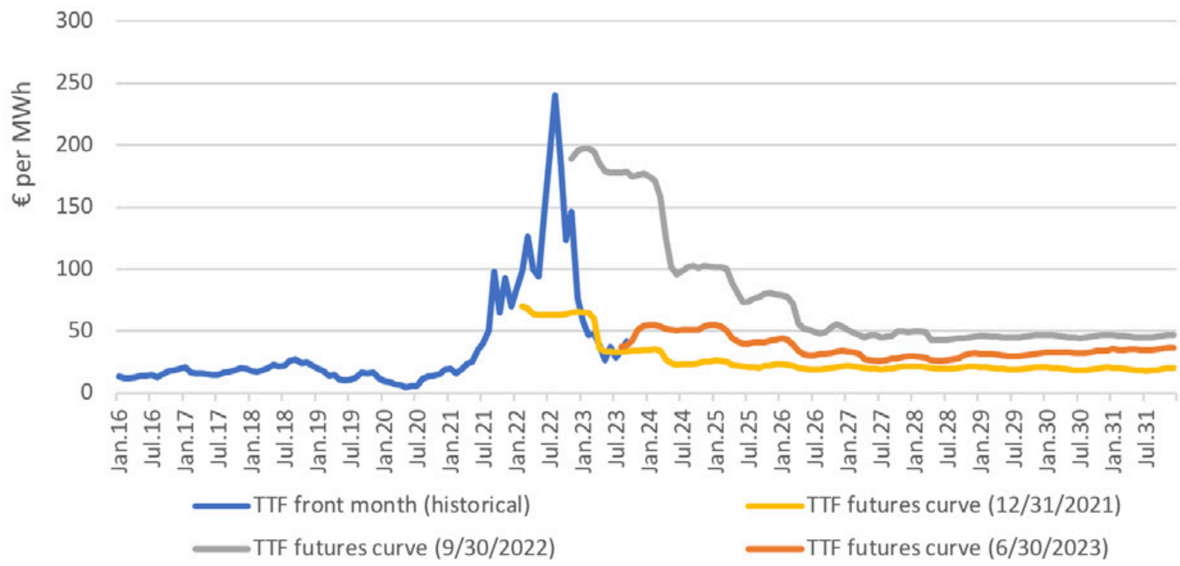
In the face of the 2022 energy crisis, the European Union adopted a set of measures to mitigate the near-term supply shock—and to eliminate dependence on imported gas from Russia over time (European Commission 2022c). The most consequential measures included the following:

- The REPowerEU plan, which set out a number of medium- and long-term measures to reduce dependency on Russian fossil fuel imports by 2027. The plan includes the ramp-up of biomethane production, the accelerated deployment of renewable energy, energy efficiency measures, hydrogen projects, heat pumps, and reforms to the permitting process for renewable energy projects.
- A new gas storage regulation that set mandatory storage targets and trajectories for EU member states to ensure that underground storage facilities were filled to adequate levels—to 80 percent in 2022 and 90 percent in subsequent years—for the winter heating season. Mandatory storage obligations are scheduled to sunset at the end of 2025, but provisions related to the certification requirement for storage operators will continue beyond 2025.
- A regulation on reducing gas demand that set a voluntary target to cut natural gas consumption by 15 percent between August 1, 2022, and March 31, 2023, from the average of the previous five years. The EU Council has the option to make the targets mandatory in the event of a supply emergency. The regulation was extended in March 2023 to cover the 2023–24 winter period.

Both the 2022 storage targets and the 2022–23 demand-reduction goals were exceeded, improving energy security in Europe. Other key policy interventions at the EU level included the adoption of a temporary wholesale gas price cap (at €180 per megawatt hour [MWh]) in October 2022 and the launch of a joint gas-purchasing platform to help member states initiate tenders and achieve better pricing terms by aggregating demand. The EU-wide gas price cap—which had been due to expire in February 2024 but was extended to January 2025 (Abnett 2023)—had not been triggered through the end of 2023, as the measure was adopted after European gas prices peaked in August 2022. The joint purchasing platform (officially launched in April 2023) has been successful in matching offers from buyers and sellers for future gas deliveries. However, the extent to which these matched volumes will translate to actual deliveries—and whether the terms achieved on the platform are more advantageous for buyers than normal tenders would have been—remains to be seen. In addition to EU-level policy action, member states, often with financial support from the European Union, accelerated the construction of LNG import and cross-border pipeline infrastructure as well. EU member states had completed construction of approximately 20 bcm of new LNG regasification capacity by the end of 2022 and had another 50 bcm under development at the start of 2023 (IEA 2022a, 10). A number of key cross-border interconnections, such as the Interconnector Greece-Bulgaria (IGB) pipeline, were also commissioned ahead of the 2022–23 winter heating season (European Commission 2022a). These interconnections improved gas flows and supply security, particularly in Central and Southeastern Europe.

The cost of energy security in Europe has been significant, as European gas prices hit new records in 2022. Although prices eased in the first half of 2023, forward curves as of mid-2023 rose and are expected to remain high until 2025–26, when a wave of new LNG supply is scheduled to arrive. The gas price at the Dutch Title Transfer Facility (TTF) is generally considered to be a price benchmark for the wider European region. The TTF benchmark is relevant for the ECA region both as an anchor for other continental European hubs (including those in Central and Eastern Europe) and as a price index in long-term pipeline gas and LNG supply contracts. TTF prices spiked to record levels in 2022 and the gradual reduction of Russian pipeline gas flows to Europe throughout the year (figure 1.4). Month-ahead TTF prices averaged €130 per MWh in 2022, a three-fold increase from 2021 and more than eight times higher than the average during the preceding five-year period. As the immediate supply concerns have eased in Europe (thanks in a large part to a very mild winter), TTF prices gradually dropped to around €30 per MWh by the summer of 2023. Market participants' aggregate price expectations, reflected in the futures curve in figure 1.4, also rose sharply during 2022 but came down significantly by the end of Q2 2023. Nevertheless, as of mid-2023, TTF prices were still expected to remain at or above €50 per MWh—substantially higher than pre-crisis levels—until 2025, when the next wave of LNG supply (led by a major expansion project in Qatar) could bring further relief.

Figure 1.4 • Actual and projected natural gas prices at the Dutch Title Transfer Facility, January 2016–July 2031



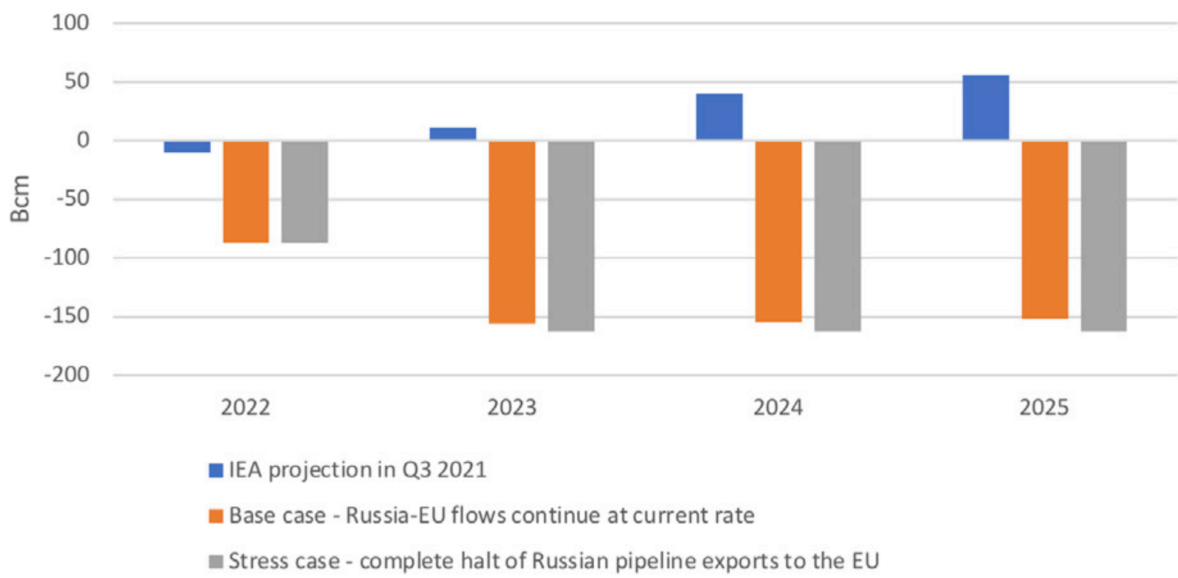
Source: ICE Index.

The impacts of the disruption of gas trade between Europe and Russia are profound. They are already apparent, not just inside the European Union but also in Russia and other parts of the region. The scale and nature of these impacts vary widely across the region. The analysis that follows highlights some of the regional differences in a post-2022 reference scenario, in which Russian flows to the European Union continue at the average rate observed in the first half of 2023, and in a hypothetical stress scenario, in which Russian pipeline gas flows to EU member states stop altogether in 2024.[7]

Impact on Russia's gas production

Russian gas production has declined substantially with the reduction of EU-Russia gas trade. Russia's domestic natural gas production declined by 11 percent (or 88 bcm) in 2022, as exports to Europe dropped (Jodi Gas 2023). Russian production is expected to slide further in 2023–25; by 2025 it is expected to be 150 bcm below its 2021 level (figure 1.5). This projection lies in sharp contrast with the International Energy Agency's 2021 forecast of production growth of 50–60 bcm during the 2021–25 period. The combined production gap of about 200 bcm is on the scale of total gas consumption within the entire ECA region excluding Russia (270 bcm) (IEA 2023c); it is roughly equivalent to the combined LNG exports from Qatar and the United States in 2021 (200 bcm) (BP 2022). The production loss between 2021 and 2025 is even greater—around 220 bcm—if the remaining Russian gas flows through Ukraine and the TurkStream pipeline are cut off to Europe in 2024, as assumed in the stress case.

Figure 1.5 • Actual and projected changes in Russian natural gas production from 2021 levels, 2022–25



With the European Union's efforts to reduce dependency on imports of Russian fossil fuels, Russia is looking for alternative export outlets for its pipeline gas. The most obvious choice is China. However, the gas source of the Power of Siberia pipeline system, which links Russia's Eastern Siberian fields with northeast China, is not connected to the upstream and transport infrastructure in northern and western Russia that previously supplied large volumes of pipeline gas to Europe. Redirection of gas exports from Europe to China via this route is thus not possible, and the ramp-up of Russian exports to China is currently limited by the development schedules of the Chayandinskoye and Kovyktinskoye fields in Eastern Siberia. Nevertheless, gas deliveries to China via the Power of Siberia line have grown ahead of schedule. Gazprom delivered nearly 23 bcm of pipeline gas to China in 2023 (3 bcm more than the original plan envisioned) and it expects to reach the pipeline's full 38 bcm capacity by 2025 (Bloomberg News 2024).

The other proposed export outlets from Russia are either disconnected from the Western producing fields and infrastructure or face lengthy negotiations and construction timelines even after a formal approval. The prime example of the first situation is the 10 bcm Far Eastern route, which is scheduled to begin deliveries from Sakhalin to Northeast China around 2026. Exemplifying the second situation is

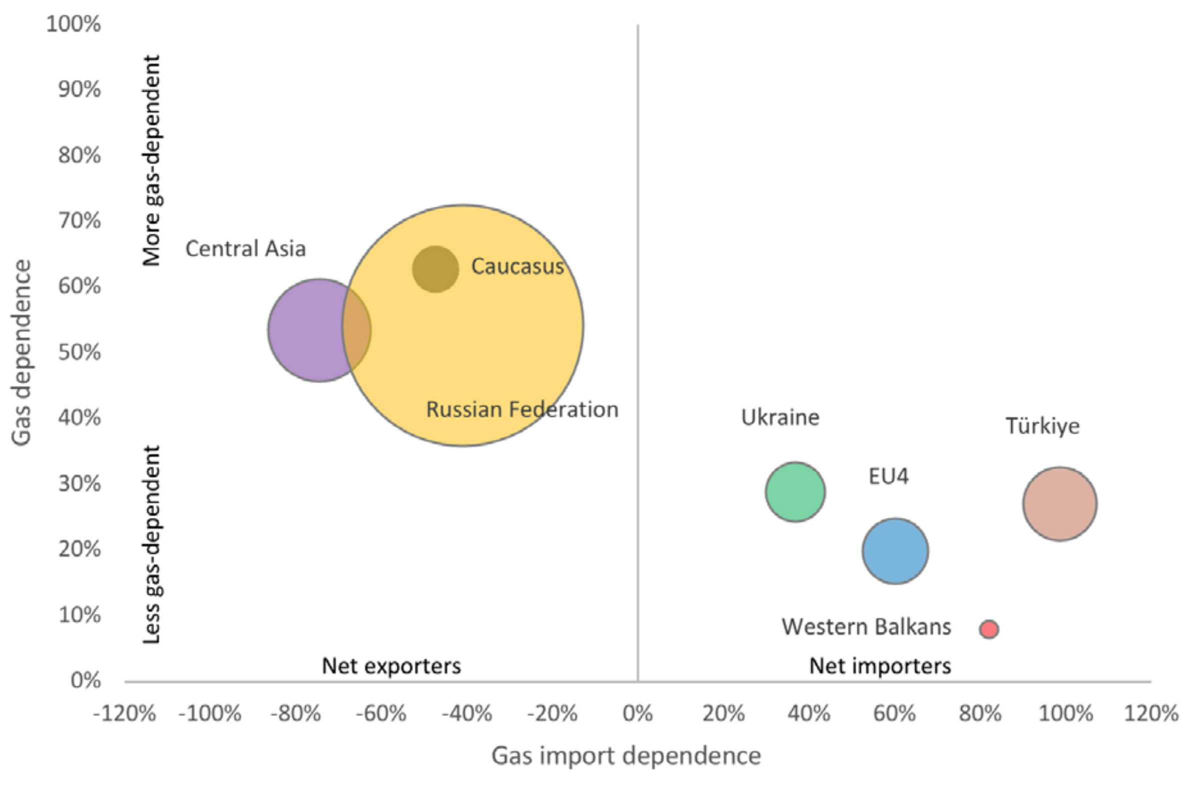
7 An overview of the modeling approach appears in part 2 of the report.

the proposed 50 bcm Power of Siberia 2 line, which would connect Russia's legacy infrastructure with the Chinese market and thus provide a real option for Gazprom to redirect gas flows to Asia, but not before the end of this decade. One possible short-term option for Russia to redirect some of its now-stranded gas resources is to supply gas via existing infrastructure to Central Asia as part of a proposed "tripartite gas union" among Russia, Uzbekistan, and Kazakhstan. The challenges and possible implications of this new trade route are analyzed in greater detail below.

Impact on countries in the region

Exposure to the gas supply shock varies widely across the region. Based on the degree of import dependence and the role of gas in the energy mix, two country groupings with distinct characteristics can be identified (figure 1.6). Countries that built gas-based economies (relying on natural gas for 50–80 percent of their primary energy supply) tend to be net exporters of natural gas. Apart from Russia, this characterization applies to Azerbaijan, Kazakhstan, Uzbekistan, and Turkmenistan. At the other end of the spectrum, countries that depend heavily on natural gas imports (in most cases from Russia) tend to have relatively low shares of natural gas in their primary energy mix (less than 30 percent). This group includes Ukraine, Türkiye, countries in the Western Balkan, and countries in the European Union, although Armenia, Belarus, Croatia, Georgia, and Moldova rank high for both import dependence and natural gas dependence.

Figure 1.6 • Gas dependence and gas import dependence in Europe and Central Asia, by country, 2020



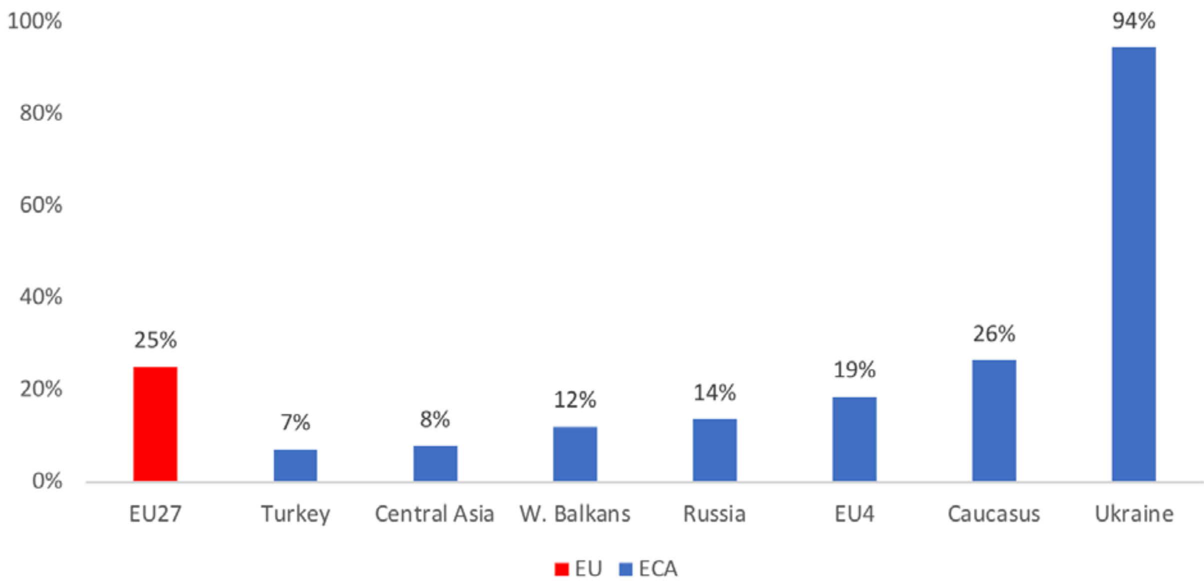
Source: IEA 2022f.

Note: The EU4 consist of Bulgaria, Croatia, Poland, and Romania.

Limited availability of underground gas storage exacerbates exposure to gas supply shocks in parts of the region. The relatively low gas dependence of the European subregions partly mitigates the possible adverse effects of Russian gas supply disruptions. But storage cover is low in the Western Balkans (12 percent) and EU4 countries (19 percent) relative to the EU average (25 percent), leaving these countries dependent on gas supply availability and cross-border pipelines from neighboring countries, especially during the peak winter period. Türkiye and Central Asia have even lower storage cover (7 percent and 8 percent, respectively); countries in Central Asia suffered episodes of gas shortages and blackouts during recent winters as a result.

Ukraine has vast underground storage capacity of more than 30 bcm—the third-largest in the world after the United States and Russia (figure 1.7). The country's immense capacity is a legacy of its former role as a major transit country and gas market. Ukraine's surplus gas storage capacity could become a valuable energy security asset for the broader European market over time. Since 2020, the regulatory framework in Ukraine has been harmonized with that of the European Union, and trade barriers have been removed to facilitate the warehousing of gas in Ukrainian storage sites by EU–based traders. Ukrainian storage was used extensively as overflow capacity for European importers during the 2020 gas glut, when EU storage sites filled up well ahead of the winter heating season and surplus gas could no longer be stored within the European Union's borders. However, geopolitical risks remain a consideration for European countries storing surplus gas in Ukraine.

Figure 1.7 • Underground storage capacity as a share of total consumption in Europe and Central Asia, by subregion, 2021

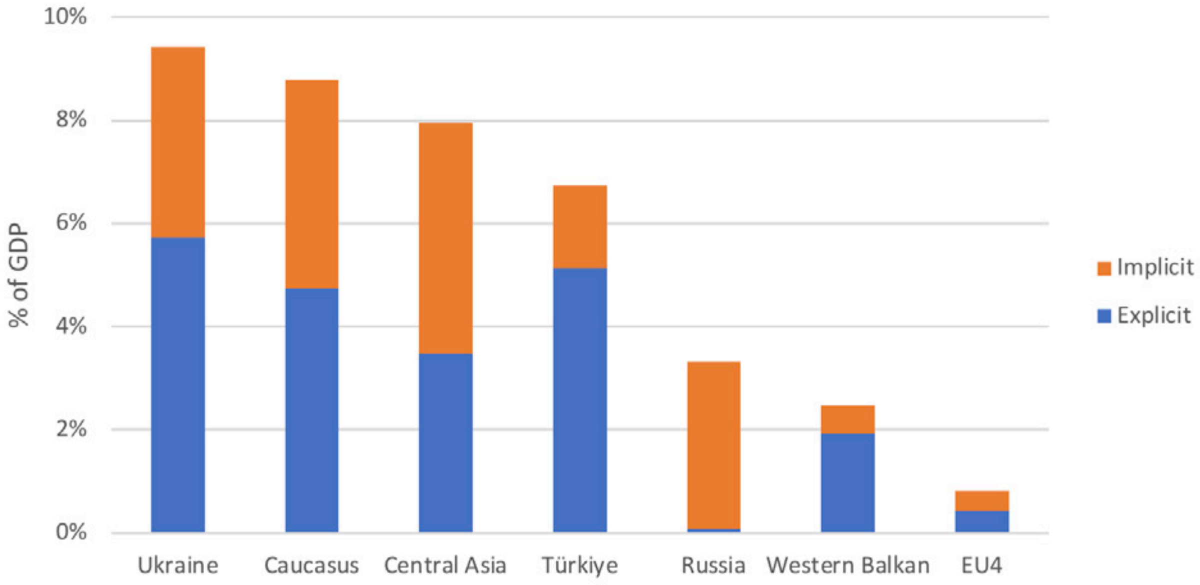


Source: IEA. 2023d, Cedigaz.

Natural gas subsidies continue to undermine investment, energy efficiency, and supply security in parts of the former Soviet Union. The legacy of heavily subsidized and artificially low natural gas tariffs; inefficient energy use; poorly capitalized, vertically integrated gas and power monopolies; and poorly maintained gas and power infrastructure are common across the region (IEA 2016). Data from the International Monetary Fund (IMF) on explicit and implicit fossil fuel subsidies (which include direct and indirect transfers to producers and consumers as well the unpriced externalities associated with the negative climate and health effects of fossil fuel use) indicate that natural gas subsidies amounted to about 2 percent of GDP in the Western Balkans and less than 1 percent in the four EU members within the ECA region in 2022 (IMF 2022). In contrast, in the Caucasus, Central Asia, Moldova, and Ukraine, implicit and explicit gas subsidies ranged from 3 percent to 9 percent of GDP in 2022 (figure 1.8). Explicit subsidies alone amounted to 0–6 percent of GCP across the former Soviet republics (3–6 percent when excluding Russia), a substantial burden by any measure.[8]

8 The IMF (2022) estimates the explicit subsidies given to natural gas producers and consumers in Russia at only $1.6 billion, a negligible fraction of the country's $1.8 trillion GDP in 2022.

Figure 1.8 • Explicit and implicit natural gas subsidies within Europe and Central Asia as a share of GDP, 2022



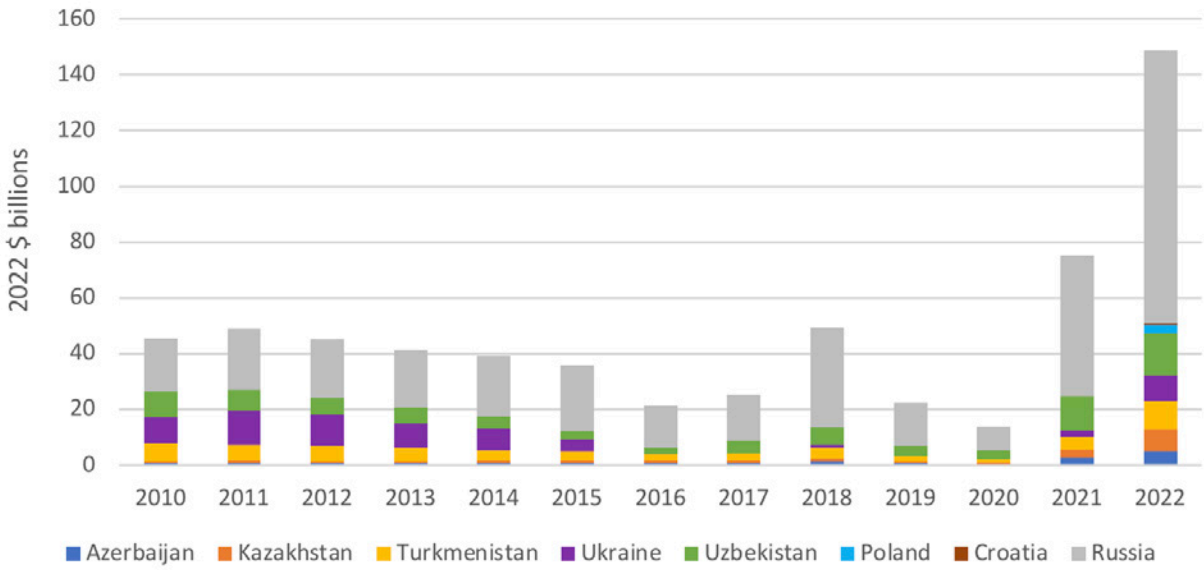
Source: IMF 2023.

Note: The Western Balkans exclude Kosovo and Montenegro, for which data were not available.

Natural gas subsidies can exacerbate energy crises in parts of the region. The persistence of high gas subsidy rates is especially problematic in net importers of natural gas (such as Ukraine), in regions where large seasonal swings in demand combine with insufficient system flexibility and storage capacity (such as Central Asia), and in countries where power and heat generation is almost exclusively fueled by natural gas (such as Azerbaijan and Uzbekistan). In such circumstances, natural gas subsidies not only discourage energy conservation, efficiency improvements, and the deployment of cleaner alternatives (such as renewables, combined heat and power plants, and heat pumps), they also perpetuate underinvestment in gas, electricity, and district heating infrastructure, increasing the risk of severe gas and power supply disruptions—and major energy crises—during periods of tight supply.

Consumption subsidies are especially harmful, because they incentivize wasteful natural gas consumption and diminish the effectiveness of demand-side mitigation measures during gas supply emergencies. The International Energy Agency (IEA) subsidy database, which uses a narrower definition than the IMF, focuses solely on consumption subsidies, calculated as the difference between market prices and end-user prices. This dataset shows that despite significant declines in gas subsidies over the previous decade (thanks in part to subsidy reforms in Ukraine, Uzbekistan, and other ECA economies), the ripple effects of the European energy crisis brought a sharp rebound in 2021–22, as surging international prices pushed up the opportunity cost of providing gas to domestic users at below market rates (figure 1.9). The increase in natural gas subsidies was especially pronounced in 2022, when the market price of gas (against which subsidy rates are calculated) reached unprecedented levels and countries with little or no subsidies in recent years, such as Croatia, Poland, and Ukraine, implemented measures to protect consumers from damaging price spikes amid the energy crisis. The structurally higher global gas price environment since 2021 makes the rapid phase-out of subsidies even more challenging, underscoring the importance of gradual reforms and the simultaneous introduction of direct transfers to vulnerable low-income consumers.

Figure 1.9 • Natural gas consumption subsidies in selected countries in Europe and Central Asia, 2010–22



Source: IEA 2023e.

Note: The IEA fossil fuel subsidy database contains information on only eight countries in the ECA region.

Gas security in the EU4 and Western Balkan countries

The risk of disruptive gas supply shortages receded in the first half of 2023 across Europe (including in the EU4 and the Western Balkan countries), but the possibility of gas shortfalls has not completely disappeared in Europe, and the energy crisis can get worse before it gets better, particularly within the next one or two years. Due to a combination of an unseasonably warm European winter, abundant LNG availability (reflecting weak demand in Asia), well-timed policy action at the national and EU level, and recently added gas infrastructure, a winter energy crisis was largely avoided in 2022/23. The European countries within the ECA region have adequate supply and cross-border capacity to substitute for any additional loss of Russian gas flows on an annual average basis. However, a complete shut-down of the remaining Russian pipeline flows to the European Union would put infrastructure to a severe test and require an exceptional degree of coordination and solidarity between neighboring states—in some cases between EU and non–EU members—to avoid localized gas shortages. The European countries within the ECA region would also depend on continuing abundant supplies of LNG and non-Russian pipeline gas to the wider European market, which would need to find its way to Eastern Europe and the Western Balkans via the existing infrastructure links. A harsh winter could still create strain and lead to periodic shortages across Eastern and Southeastern Europe, even if all the other conditions of gas supply adequacy are fulfilled.

The EU4 now enjoy a high degree of gas interconnectivity and access to LNG via Croatia, Poland, Greece, and Türkiye. Russian gas supplies to Poland and Bulgaria were cut off during 2022 because of these countries' unwillingness to pay for their imports in rubles. Romania has significant domestic production, low import dependence, and cross-border connections to provide alternatives. Croatia's LNG terminal offers a measure of gas supply security not just for Croatia but also for its neighbors.

Gas demand in the Western Balkans is low, but the region is heavily import-dependent for its supply—and there is little flexibility in the routes incoming supplies must take. The Western Balkans is a very small market for natural gas, with total consumption of less than 4 bcm in 2021. Import dependence is very high, at more than 80 percent, and the region's gas supply is still sourced predominantly from Russia. Model results indicate that more than 90 percent of the region's gas imports could be replaced using alternate transit routes through 2025 if the remaining Russia–EU transit corridors are completely shut down. Under this stress scenario, however, the remaining supply shortfall would have to be met by curtailments in demand.

Gas security in Central Asia

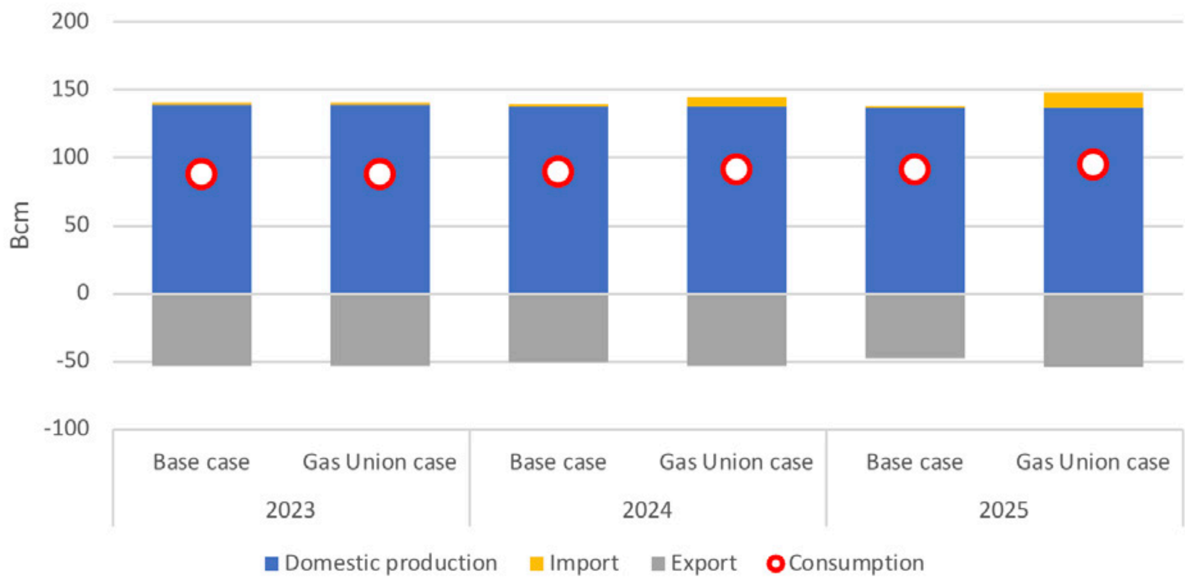
In the short term, Central Asia faces a tightening gas supply balance and ultimately may have to choose between forming a Central Asian Gas Union with Russia or reducing exports to China. In the medium term, decarbonization (including through energy efficiency and a shift away from natural gas to renewables) can reduce gas import dependency in the region's net importing countries. Central Asia has traditionally been a large net exporter of gas. However, the region's gas balance is tightening as a combination of rapidly growing demand and stagnating production (especially in Kazakhstan and Uzbekistan) erodes these countries' ability to meet export commitments to China and peak winter demand at home. In 2021, Central Asia exported a combined 42 bcm to China via the three branches of the Central Asia–China pipeline system and another 15 bcm to Russia. Kazakhstan also reimported nearly 3 bcm of processed gas from Russia, because of the lack of sufficient gas-processing capacity at home (BP 2022). Central Asian gas exports to China were down by almost 5 percent in 2022. Kazakhstan and Uzbekistan registered much sharper export declines (26 percent and 42 percent, respectively), and both countries were forced to suspend gas deliveries to China completely during the 2022/23 winter's energy crisis to cope with severe domestic gas and power shortages (BP 2022). Kazakhstan and Uzbekistan could see their exports to China decline further in 2023 and beyond. In early 2023, Kazakhstan's government signaled that no gas deliveries should be expected in China during the next heating season (Eurasianet 2023).[9] Uzbekistan's government also indicated on multiple occasions that it plans to end natural gas exports by 2025 (Gazeta.uz 2020).

A gas union among Russia, Kazakhstan, and Uzbekistan could help plug Central Asia's supply gap in the short term and sustain healthy levels of pipeline gas flows from Central Asia to China, but it is not without challenges. In November 2022, Russia proposed a tripartite gas union with Kazakhstan and Uzbekistan to promote Russian gas shipments to the two Central Asian countries as well as China. Kazakhstan and Uzbekistan first rejected the proposal, but after the 2022/23 winter energy crisis (and Russia's willingness to drop demands for the takeover of the gas transmission networks in both countries), the two Central Asian countries signed separate cooperation roadmaps with Gazprom in January 2023 to study the technical possibilities of supplying Russian gas to Central Asia and China as part of a gas union. In June 2023, Uzbekistan signed a two-year short-term contract with Gazprom for the delivery of up to 2.8 bcm a year. The first deliveries under the regional scheme were reported to have started in October 2023 (Reuters 2023a), after some technical upgrades to the Central Asia–Central pipeline system in Q3 2023 to enable reverse flows from Russia to Central Asia.[10] The medium-term plans call for the delivery of up to 10 bcm of Russian gas per year to Central Asia, of which about 4–6 bcm could be reexported to China (Losz and Mitrova 2023). Doing so appears feasible in the 2025 time frame, although additional infrastructure upgrades would likely be required to accommodate the higher flows. Modeling results indicate that an additional 10 bcm of Russian gas in the region by 2025 would help maintain stable export levels from Central Asia to China and support growing domestic consumption within the region in 2023–25 (figure 1.10). The base case without a gas union would see Central Asia's production and export levels contract between 2023 and 2025. Net Zero scenarios deliver the best energy security outcome for Central Asia, with higher self-sufficiency than fossil fuel–based scenarios.

9 The contract was subsequently extended to 2026, though volumes were not disclosed (Reuters 2023b).

10 Historically, the Central Asia-Central pipeline system was used to export Central Asian gas to Russia.

Figure 1.10 • Projected natural gas balance in Central Asia in the base case and gas union scenarios, 2023–25

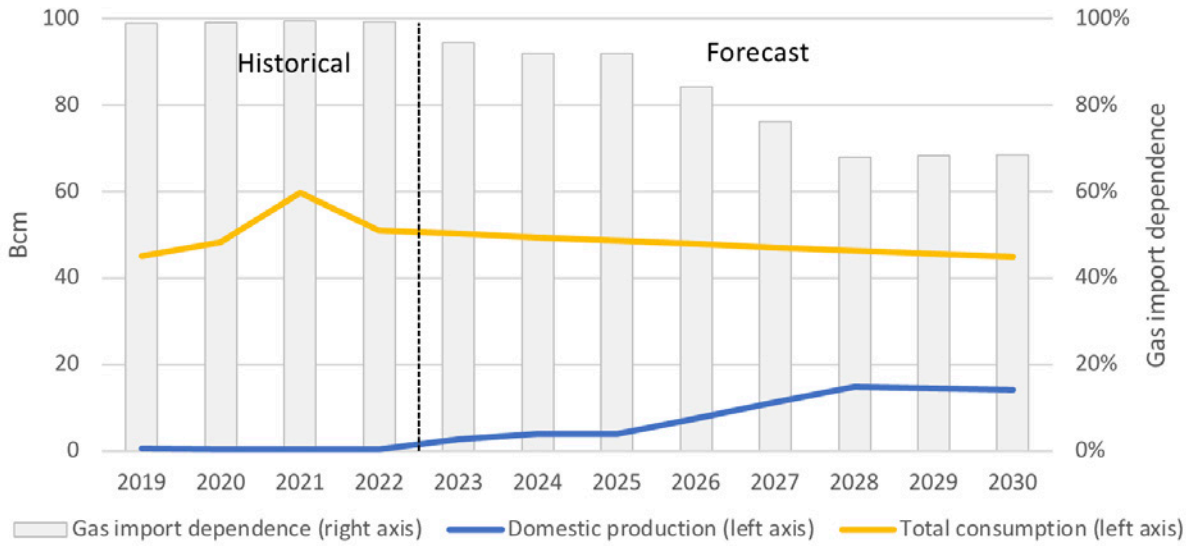


The limits of Türkiye's ability to absorb Russia's surplus gas

Russian pipeline gas flows to Türkiye have continued uninterrupted throughout the energy crisis, but Türkiye's ability to absorb significantly more gas from Russia is limited in the medium term. Despite the ongoing European energy crisis, pipeline gas deliveries to Türkiye (via the Blue Stream and TurkStream 1 pipelines) have remained relatively stable. Given the spare capacity on the existing pipeline routes from Russia and the diverse import mix of Türkiye, which allows for some rearrangement of inflows into the country, the possibility exists for Russia to place additional volumes of its stranded gas in Türkiye. However, this analysis shows that the additional gas volume Russia could export to Türkiye is relatively modest.

The domestic gas balance in Türkiye is shifting decisively toward lower gas import requirements in the medium term (figure 1.11). Gas consumption varied widely in recent years (ranging between 45 bcm in 2019 and 60 bcm in 2021), with much of the fluctuation explained by sharp swings in hydroelectricity generation in the power sector and temperature-driven heating demand for buildings. Gas consumption in 2022 reached 51 bcm (Jodi Gas 2023), a 14 percent decline from the previous year, driven by demand erosion caused by high prices and lower gas-to-power demand as a result of higher coal-fired, hydro, and wind generation. Medium-term trends indicate further demand declines: Renewables and nuclear energy are expected to squeeze gas use for power generation, and energy efficiency can shrink energy demand in buildings. At the same time, domestic production (which averaged only around 0.4 bcm during the 2019–22 period) is on course for an unprecedented increase, thanks to the 2023 start-up of Sakarya, the largest natural gas field in the Black Sea discovered to date. The first phase of the project, which started in April 2023 (Offshore Technology 2023), is set to reach peak production at around 3.7 bcm/year (10 mcm/day) by 2024; total output from the field could reach up to 14.6 bcm/year (40 mcm/day) by 2027–28, following the completion of the planned second phase of the project (Bloomberg 2023). The simultaneous shrinking of domestic consumption and surging domestic production could squeeze Türkiye's gas import requirements by around 6 bcm by 2025 and close to 20 bcm within the 2028–30 period compared with 2022 levels. This change would help reduce Türkiye's gas import dependence from close to 100 percent until 2022 to just over 90 percent by the mid-2020s and to less than 70 percent by the end of the decade (see figure 1.11). At the same time, the room for Russian gas to maintain—let alone increase—its share in the Turkish gas supply mix would be severely constrained, unless it can squeeze out other import sources from Türkiye's gas balance in the years ahead.

Figure 1.11 • Actual and projected gas production, consumption, and import dependence in Türkiye, 2019–30



Russia can increase its market share in Türkiye at the expense of the country's other suppliers, but only modestly and only temporarily. Russia has long been Türkiye's primary gas supplier, accounting for about 40 percent of total imports in 2022 (figure 1.12). The other two pipeline gas suppliers, Iran and Azerbaijan, represented 17 percent and 16 percent of Türkiye's import mix, respectively.[11] The remaining 27 percent came from a wide range of LNG suppliers,[12] with the United States, Algeria, and Egypt being the three largest sources in 2022 (Mees 2023). Given the prospects of rising domestic production, limited consumption growth, and contractual commitments, the additional volume of Russian gas that could be exported to Türkiye is modest. In a hypothetical scenario in which no new pipeline gas or LNG contracts are signed and all other flexible import sources (including spot LNG purchases) are kept to zero, the maximum amount of Russian gas Türkiye can absorb would peak at around 30 bcm in 2025, nearly 9 bcm above 2022 levels and close to the combined nameplate capacity of the Blue Stream and TurkStream 1 pipelines (31.75 bcm). However, the market space for Russian gas within Türkiye would shrink to around 23 bcm by 2030 (only marginally higher than 2022 deliveries of 21.6 bcm) following the ramp-up of the second phase of the Sakarya gas field toward the end of the decade, even if none of Türkiye's import contracts are extended beyond their current term.

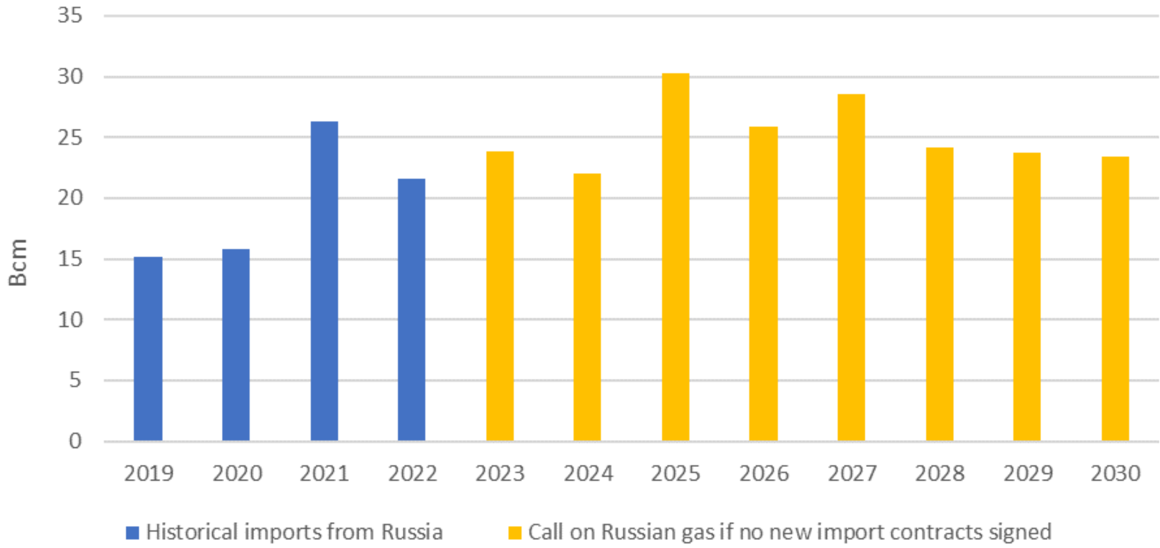
---

11 Pipeline gas imports from Russia to Türkiye arrive via the Blue Stream and TurkStream 1 pipelines across the Black Sea (with nameplate capacities of 16 bcm and 15.75 bcm, respectively). The restart of the Trans-Balkan pipeline—which could theoretically deliver another 16 bcm of Russian gas to Türkiye via Ukraine, Moldova, Romania, and Bulgaria—is not feasible in the foreseeable future, as it would require additional Russian gas transit via Ukraine and the pipeline is currently used in partial reverse mode to transit gas to Romania and Bulgaria from a southerly direction. Pipeline gas supplies from Iran are delivered to Türkiye via the Eastern Anatolian Natural Gas Main Transmission Line (with a nominal capacity of 10.4 bcm) under a 15-year contract running until 2026. Türkiye's annual contracted quantity from Iran is about 10 bcm, but the minimum take-or-pay volume is estimated at only around 7 bcm. Gas imports from Azerbaijan are currently supplied from the Shah Deniz 2 project via the TANAP pipeline under a 6 bcm long-term gas contract that ends in 2044. Supplemental short-term volumes (totaling 2.5 bcm in 2022, 3.5 bcm in 2023, and 5 bcm in 2024) are also provided via the South Caucasus Pipeline from the Shah Deniz 1 development during 2022–24.

12 LNG contracts covered approximately 7 bcm of supply. The remaining LNG imports were delivered on a spot and short-term basis. Türkiye's current LNG contracts with TotalEnergies (1.6 bcm) and Sonatrach of Algeria (5.4 bcm) will expire at the end of 2023 and 2024, respectively. The only source of firm LNG supply after 2024 is a recently signed 10-year LNG contract with Oman LNG that would deliver 1.4 bcm from 2025. Türkiye's current LNG import capacity is much larger, at 41 bcm as of mid-2023.

Figure 1.12 • Actual and hypothetical Turkish imports of Russian gas, 2019–30

In a hypothetical scenario where no new pipeline gas or LNG contracts are signed



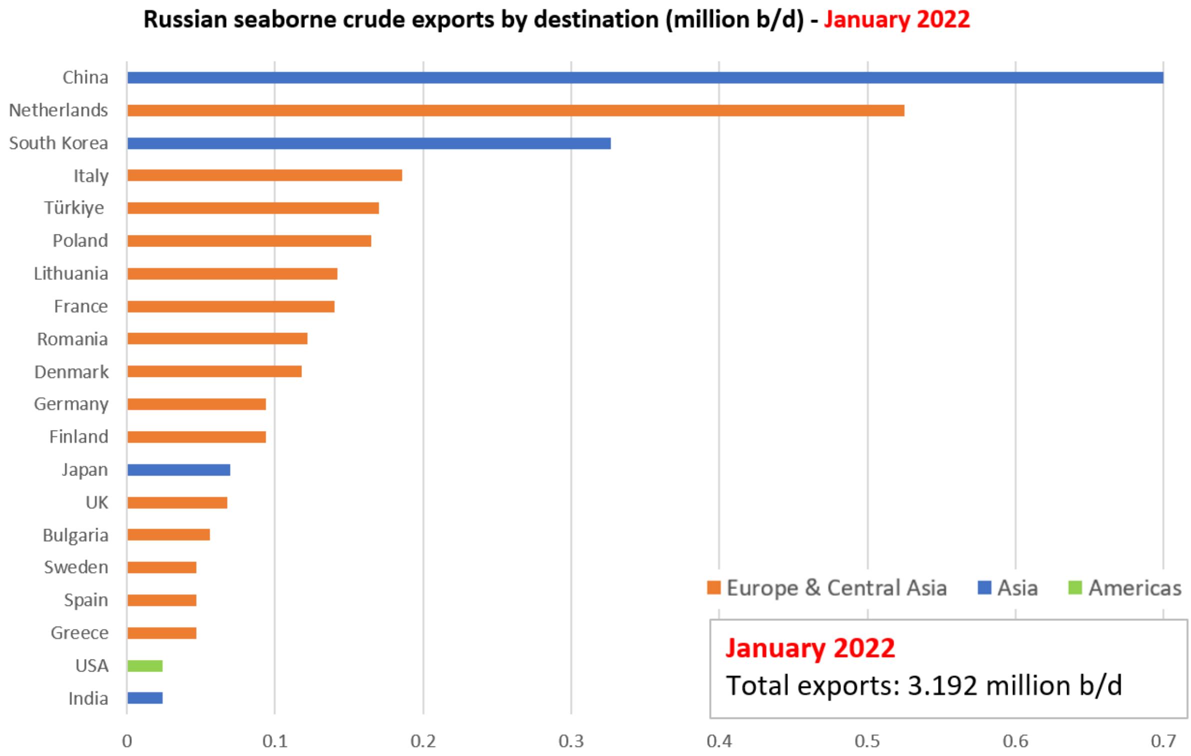
Source: Historical data are from Republic of Türkiye Energy Market Regulatory Authority (EPDK); projections are based on the authors' analysis.

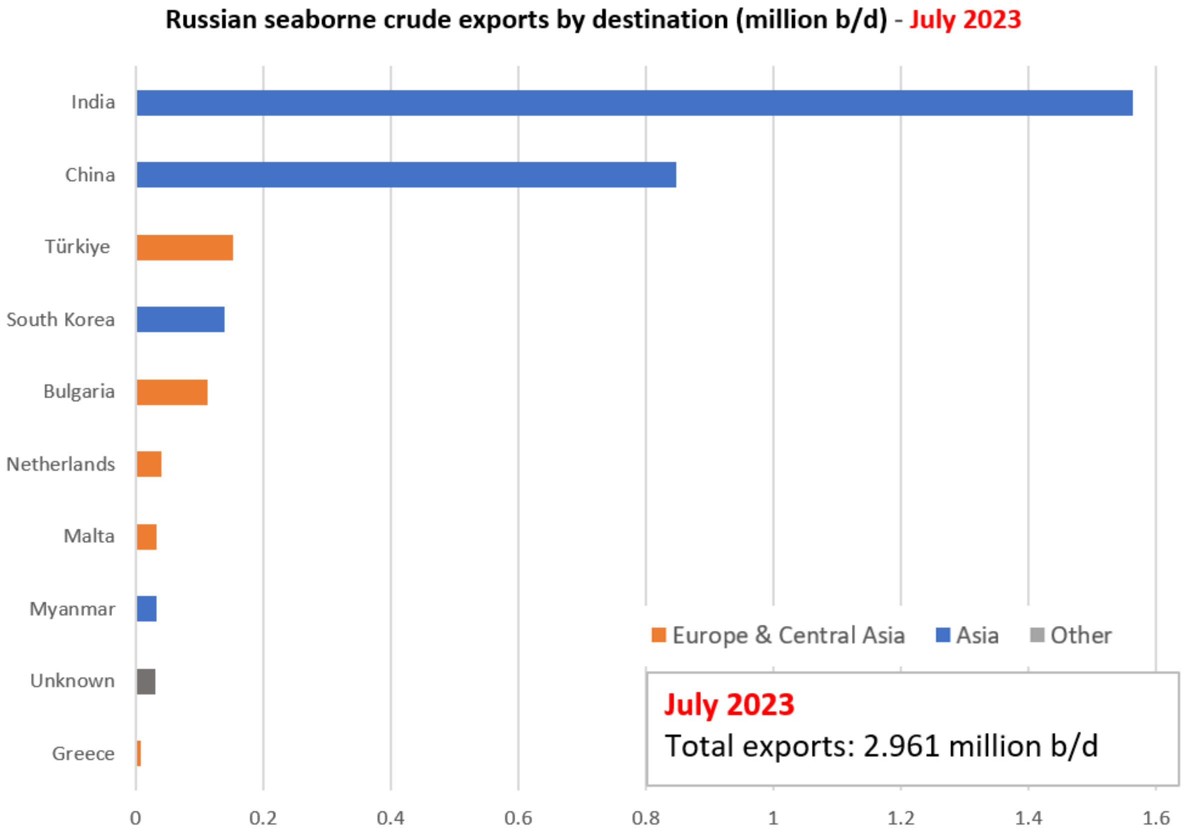
OIL SECURITY: ONGOING SHIFTS

Since February 2022, global oil markets have shifted significantly, especially in the EU and ECA. Before the war in Ukraine, Europe was Russia's main export market, for both crude oil and refined oil products, such as diesel. Subsequently, several Western countries started to reduce their purchases of Russian oil. EU embargoes on oil imports and price caps coordinated by the G7, Australia, and the European Union came into force in late December 2022 and early February 2023.

The sanctions on Russia and the imposition of G7 price caps triggered a major upheaval in global oil trade flows. The loss of its traditional customers in Western Europe and the ECA region has forced Russia to find alternative buyers. Russian crude and oil product trade flows have shifted east and south, trading at heavy discounts after the introduction of Western sanctions (figures 1.13 and 1.14). Indian imports of Russian crude rose by 6,400 percent between January 2022 and July 2023, making it Russia's largest crude buyer. Türkiye, China, India, and several countries in the Middle East and North Africa region and in Africa are now the main purchasers of Russian oil products.

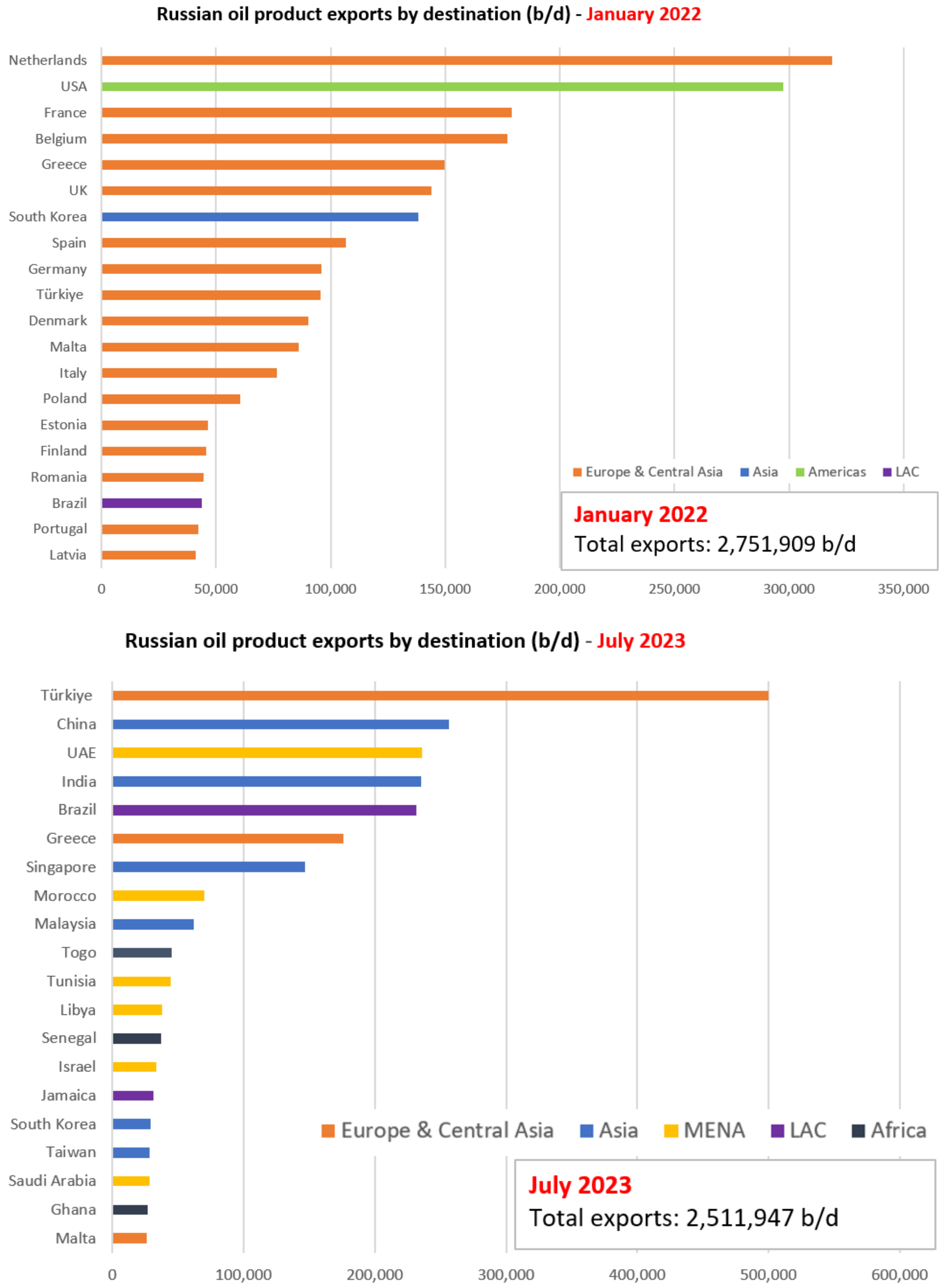
Figure 1.13 • Seaborne crude oil exports by the Russian Federation, by destination, January 2022 and July 2023





Source: S&P Global Commodity at Sea.

Figure 1.14 • Exports of Russian oil products, by destination, January 2022 and July 2023

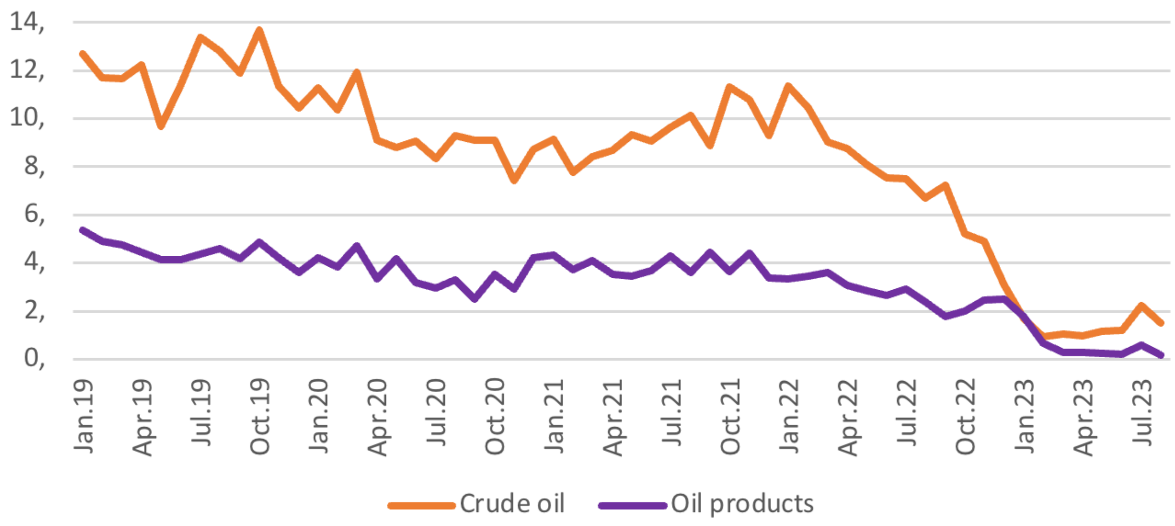


Source: S&P Global Commodity at Sea.

Amid sanctions and a G7 price cap, Russian oil exports have held up relatively well. Russian-origin seaborne crude shipments averaged 3.0 million barrels a day (b/d) in July 2023 slightly below average pre-war levels of 3.2 million. However, contract prices for Russian Urals crude oil have significantly diverged from the benchmark Brent price, with Urals selling at a discount of more than $30/barrel at times between March 2022 and April 2023. Discounts on Russian crude narrowed in recent months to around $18 in December 2023, as Russia sources more non-G7 shipping capacity to sidestep G7 price caps on its exports.[13]

EU imports from Russia dropped by over 90 percent, but several EU countries were continuing to import as of September 2023. Before the war in Ukraine, many ECA countries depended on Russia for crude and oil product supplies. With the imposition of Western sanctions and EU import bans, imports of Russian oil dropped significantly, especially among EU countries, whose imports of oil and oil products from Russia fell to 90 percent below their pre-war levels (figure 1.15). The EU oil import ban exempts oil imports via the Druzhba oil pipeline, which connects Russian oilfields with refineries in the Czech Republic, Germany, Hungary, Poland, and the Slovak Republic. Germany voluntarily stopped importing Russian crude via the pipeline at the end of 2022, and the Russian oil pipeline company Transneft stopped supplying Poland at the end of February 2023. The vast gap left by Russia has been filled by a range of countries, including Angola, Azerbaijan, Brazil, India (diesel), Norway, Saudi Arabia, the United Arab Emirates, and the United States.

Figure 1.15 • EU imports of Russian crude oil and oil products, January 2019–April 2023 (millions of tonnes)

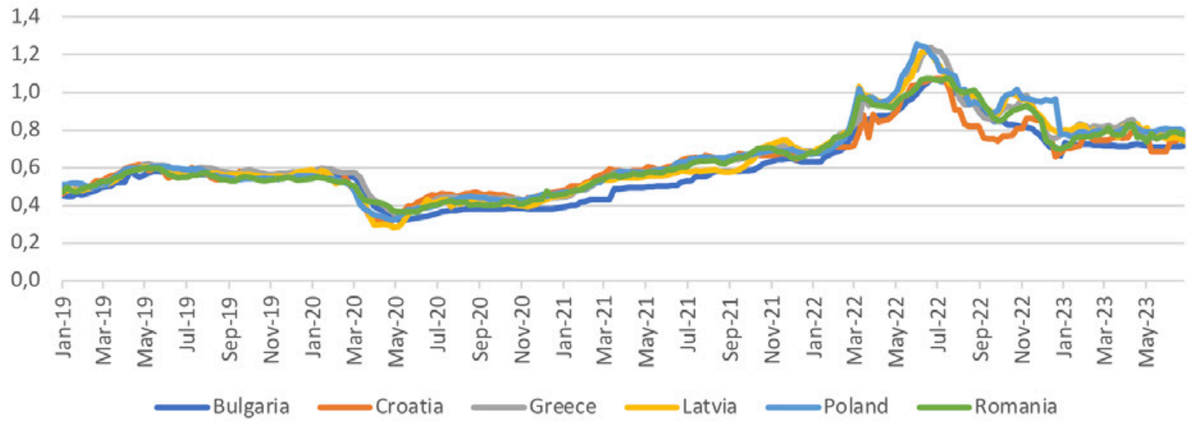


Source: Eurostat.

Many countries have experienced significant volatility in their domestic fuel prices, with sharp increases in March and June 2022 as a result of the rapid and significant shifts in oil trade dynamics within ECA (figure 1.16). Gasoline prices in Poland were 80 percent higher in June 2022 than in January 2022, for example.

13 Security risks on these vessels is growing; on August 5, 2023, a Russian tanker carrying fuel oil was attacked in the Black Sea.

Figure 1.16 • Domestic gasoline prices without taxes in selected countries in Europe and Central Asia, January 2019–July 2023 (€/liter)



Source: European Commission 2023.

Globally, energy commodity prices have been rising since 2021, as economic recovery from the COVID-19 pandemic led to a rebound in energy demand while supply remained constrained. The war in Ukraine exacerbated these trends, leading to significant price volatility in energy commodities throughout 2022.

There was a global proliferation of fuel subsidies and price controls in 2022, as governments tried to shield consumers from rising and volatile fuel prices. More than 80 countries implemented new fuel price controls in 2022. Within the ECA region, several countries instituted new fuel subsidies, price controls, or fuel tax reductions (see details in appendix 4, table A4.1). In 2023, most EU member countries reversed gasoline and diesel excise duty reductions, most of which returned to the rates in place before the war in Ukraine. The European Union requires member states to levy a minimum excise duty of €0.36 per liter on gasoline. As of July 2023, only Bulgaria, Hungary, Romania, Malta, and Poland were charging the minimum tax rate; all other EU countries levied higher excise duties on gasoline.

Oil price volatility is likely to persist globally. The ECA region is likely to be exposed to oil trade and price volatility, a result of the following factors:

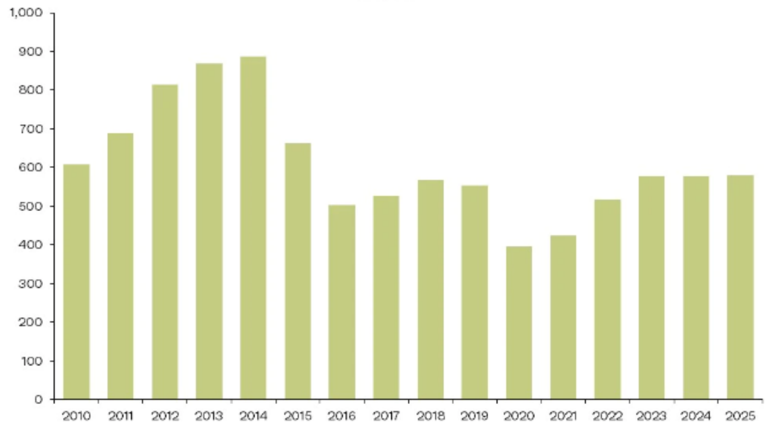
- ***Transportation costs are higher.*** The rerouting of the global oil market has come at a significant cost. Oil exports are now traveling longer distances than ever before, from Russia to India and China and from the United States, Africa, and the Middle East to Europe, increasing freight costs.

- ***Global oil supply remains volatile.*** The OPEC+ alliance voluntary cut oil production in 2023. OPEC+ leaders Saudi Arabia and Russia are resolved to keep tightening the oil market; on August 3, 2023, they announced that they would extend their supply cuts through at least September. Dated Brent prices rose 12.3 percent between the beginning of July and hitting $84.18/barrel on August 3, following the announcement.

- ***Even short-term oil demand estimates remain uncertain, because of the lack of clarity on prospects for the oil market.*** In July, the IEA cut its 2023 oil demand growth forecast by 220,000 barrels a day to 2.2 million. In contrast, OPEC revised up its 2023 global oil demand growth forecast to 2.44 million barrels a day in its report released the same day as the IEA report.

- ***Investment in upstream oil is becoming riskier, because of rising global climate ambitions.*** Global upstream investment in oil and gas peaked in 2014 at around $900 billion; it fell to $500 billion by 2016, following the 2015 oil price crash. The COVID pandemic, with the ensuing decline in oil demand, further reduced investment in upstream, dragging total investment to a record low of $400 billion in 2020. Although the recent oil price recovery induced upstream investments in 2022 to $500 billion, they are 44 percent below 2014 levels (figure 1.17). Despite the decline in investments, oil supply still rose 3 percent between 2014 and 2022, thanks to significant reduction in drilling costs and production efficiency gains. Based on JP Morgan Commodities Research estimates, upstream oil capital investments will need to stay at the current levels of $500 billion per year to ensure that demand and supply balance by 2030. However, with rising global ambitions on climate change and a focus on reducing dependence on fossil fuels, securing investment in upstream oil sector is likely to be challenging.

Figure 1.17 • Global upstream investments in oil and gas, 2010–26 ($ billion)



Source: Rystad Energy 2023a.

ENERGY SECURITY AND THE ENERGY TRANSITION

Doubling down on the clean energy transition helps countries in the ECA region diversify their energy mix. Increasing the share of renewables across ECA is one of the main levers for diversifying the energy mix. Investments in energy efficiency moderate growth in energy demand, limiting the need for fossil fuels in the energy mix. Electricity (which accounts for a 47 percent share of total final energy consumption, TFC, in 2060 in the Net Zero scenario, up from 16 percent in 2019) and low-carbon hydrogen-based fuels (13 percent of TFC in 2060, up from basically zero today) are the also main contributors to the diversification of energy supply. Investments in energy trade, smart energy network infrastructure, renewables, low-carbon hydrogen and energy efficiency can be designed to also contribute to resilience to climate shocks, extreme weather events.

Increasingly competitive renewable energy generation enables countries to increase the share of domestic energy resources and reduce their dependencies on fossil fuel imports. Renewable energies, in particular solar and wind, are set to grow more rapidly than any other form of energy in the power sector (contributing around 83 percent of power generation in 2060 in the Net Zero scenario). Electrification of end uses, renewables-based hydrogen production, and a growing share of domestic renewable power generation all help reduce the need for fossil fuel imports.

Shifting to net zero pathways with domestic low-carbon energy supplies can reduce fossil fuel import bills in many ECA countries. Projected cumulative savings are $146 billion in Türkiye and $67 billion in Uzbekistan by 2060 (World Bank 2022b, 2023b. Coal, oil, and natural gas imports have put a strain on the trade balances of many importing countries in the ECA region and exposed countries to potential supply disruptions and risks associated with fluctuations in international fuel prices. Countries can reduce import bills for fossil fuels across all sectors by tapping domestic low-carbon energy sources and increasing the share of electricity and hydrogen. The increasing use of electricity in transport (44 percent of TFC in transport in 2060) reduces spending on oil imports. Electric heat pumps are projected to provide 45–95 percent of heating in residential buildings in the Net Zero scenario in 2060, depending on the subregion. Low-carbon hydrogen and electrification reduce the need for fossil imports as industrial sectors are decarbonized.

The energy transition does not eliminate energy security considerations. The need to invest adequately in low-carbon technologies; access clean energy technologies and critical minerals; and address climate resilience, digitalization, and cybersecurity all become increasingly important aspects of energy security.

The availability of critical minerals will be an important determinant of the pace of the energy transition, in ECA and globally. Demand for critical minerals—such as key components of electric vehicle batteries—is set to increase substantially over the next several decades. Building stable, secure, and resilient supply chains for the minerals critical to the clean energy transition is important. The ECA region has critical mineral and rare earth element resource potential (e.g., for commodities such as bauxite, chromite, copper, iron ore, manganese, titanium, uranium, and zinc), but the extent of the region's mineral resource potential has not been fully determined. The use of modern exploration technologies and investment will be essential to unlocking the complex geology associated with these resources.

Employment, inclusiveness, and equity all need to be part of the energy security equation. The energy transition will have a profound impact on people and communities, especially with regard to employment, inclusiveness, and equity, all of which need to be addressed in order to ensure public support. Fossil fuel subsidies distort markets, send the wrong price signals to users, widen fiscal deficits, and discourage the adoption of cleaner renewable energies. But removing, reducing, or reforming them is politically challenging. Employment in the upstream sectors remains the backbone of entire communities in certain regions. Fossil fuel producer and exporter economies must address the burden of expected declines in oil and natural gas revenues and its impact on their balance sheets as clean energy transitions advance. Embracing clean technologies will give enterprises an opportunity to upgrade their production, connect to global value chains, and help create new jobs.

* * *

The focus shifts now from energy security in the near term to the longer-term transition to clean and sustainable energy from diversified sources, including those available domestically. Implied in the analysis is that, while predicting energy security decades into the future is an uncertain pursuit, diversification is likely to promote security, just as dependence on one or just a few sources erodes it. Part 2 therefore presents a pathway for the region to reach a net zero energy future by 2060 based on the results of a model built specifically for this report.

PART 2 • THE ENERGY TRANSITION: A PATHWAY TO A NET ZERO REGION BY 2060

Progress in Europe and Central Asia toward a net zero carbon economy is a mix of ambitious commitments and notable gaps in climate action. The region's wide range of net zero targets and greenhouse gas (GHG) emission levels highlight the need for collaboration to align climate change mitigation strategies with global goals. By adopting more ambitious net zero targets and implementing effective policies, ECA countries can make significant progress toward reducing their GHG emissions and contributing to the global fight against climate change. This second part of the report lays out a vision for every ECA country, including those not yet covered by published Country Climate and Development Reports (see appendix 5 for the status of CCDRs).

Nine ECA countries have set national net zero targets. Five of them—Armenia, Bulgaria, Croatia, the Kyrgyz Republic, and Romania—aim to be net zero by 2050. Türkiye's target is set for 2053. Kazakhstan, the Russian Federation, and Ukraine are looking at a more distant horizon (2060). Most of the region's countries have not set targets; they include Albania, Azerbaijan, Belarus, Bosnia and Herzegovina, Georgia, Moldova, Montenegro, North Macedonia, Poland, Serbia, Tajikistan, Turkmenistan, and Uzbekistan (data were not available for Kosovo).[14]

Average per capita greenhouse gas (GHG) emissions in the region stand at 11.4 tonnes of carbon dioxide equivalent per capita (tCO_2e/capita). This figure is well above the EU average of about 6.97 tCO_2e/capita and the world average of 5.94 tCO_2e/capita, but they range widely by country (appendix 5). Turkmenistan is the largest per capita emitter, at 32.18 tCO_2e, followed by Russia (16.18), and Kazakhstan (15.72). Hydro-rich countries are the lowest per capita emitters: Albania (2.9), the Kyrgyz Republic (2.5), and Tajikistan (1.9).

The energy sector is by far the largest emitter across ECA economies. The sector represents more than 71 percent of historical GHG emissions by the region (through 2019). Power is the largest culprit (41 percent), followed by transport (23 percent), commercial and residential buildings (16 percent), and industry (15 percent).

To explore possible decarbonization pathways for the region, an original model was built for this report. Data on the region's entire energy system were embedded in a KINESYS (Knowledge-based Investigation of Energy System Scenarios) model (developed using the TIMES model generator of the Energy Technology Systems Analysis Programme of the International Energy Agency– ETSAP) (IEA-ETSAP). The model was enriched by World Bank knowledge and analytics-driven subsectoral insights to represent electricity, gas, and oil trade flows across the ECA region, the European Union, and the rest of world, assuming gas pipeline flows/capacities as of May 2023. Amid the high degree of technological uncertainties (especially regarding low-carbon hydrogen, carbon capture and storage [CCS], and carbon removal), macroeconomic uncertainties (especially GDP growth), and geopolitical uncertainties, several stress tests and sensitivities were also considered. Appendix 1 describes the model's methodology and the sources of the data used.[15]

The model has two scenarios: A reference scenario and the Net Zero 2060 scenario. The reference scenario shows an increasing emissions trajectory. It is a least-cost scenario in line with the World Bank's long-term country development projections in ECA without constraints on or policies related to emissions.

---

14 Some EU candidate countries, such as the Western Balkans, have declared an ambition to work with the European Union toward a net zero European continent by 2050. But this subregional declaration cannot be interpreted as a national commitment, which every country must make if the direction of emission trajectories is to be changed.

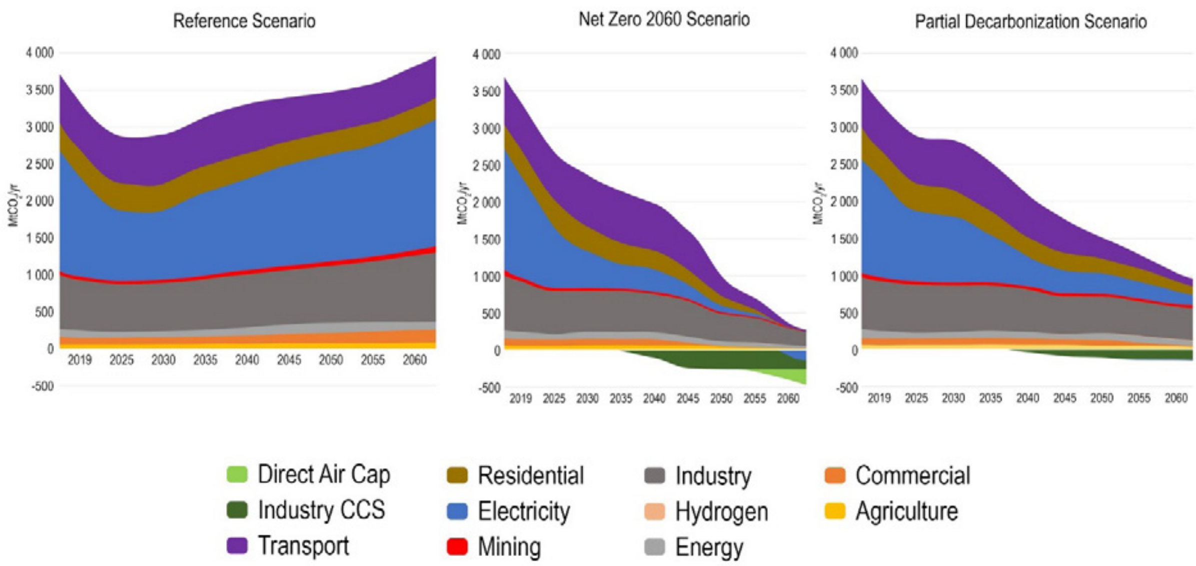
15 Unless otherwise noted, the graphs and charts in this part of the report are the authors' original work drawn from the model results.

This scenario presents a conventional energy system evolution pathway, as a reference point to convey the additional investment and policy packages needed for the energy transition in ECA beyond the existing economic drivers (e.g., conservative cost reduction from learning curves and cost-effective energy efficiency measures).

The Net Zero 2060 scenario presents a possible and ambitious least-cost pathway for ECA to decarbonize its energy system by 2060 while contributing to the larger effort to keep the global temperature rise below 2°C. According to the model results, to achieve carbon neutrality in 2060, the power systems of the 23 ECA countries must be net zero by 2040, carbon neutrality of commercial buildings must be achieved by 2050, and carbon neutrality of residential buildings must be achieved by 2055. Industry and transport are the sectors hardest to abate; they rely on carbon removal technologies even in 2060 for their decarbonization. These technologies include a combination of gas with CCS, bioenergy with CCS, and carbon removal.

Current ambitions (the partial decarbonization scenario) will not achieve a Net Zero ECA in time to help limit the global temperature increase to 1.5°C–2°C. Based on the targets announced globally, the ECA partial decarbonization scenario achieves only 65 percent decarbonization by 2050 and 73 percent decarbonization by 2060 (compared with 2019). This scenario also results in more stranded assets and higher economic costs of pollution, as well as higher fossil fuel bills for importing countries. Figure 2.1 compares sectoral emissions under the three scenarios.

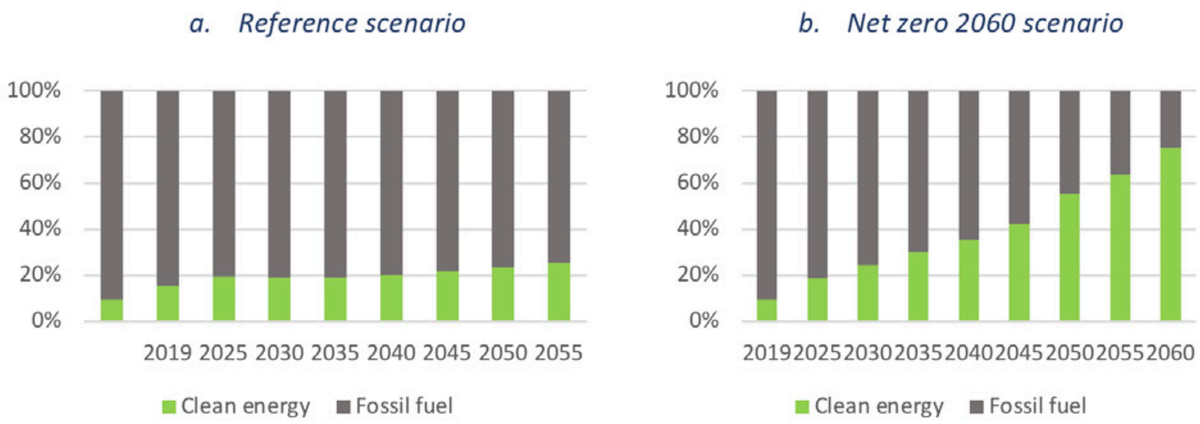
Figure 2.1 • Actual and projected energy-related greenhouse gas emissions by sector in Europe and Central Asia under the reference, partial decarbonization, and Net Zero 2060 scenarios, 2019–60



ECA's energy transition requires that over the next 10 years both supply and demand begin a decisive switch to clean technologies—notably renewables and nuclear on the supply side and EVs and heat pumps on the demand side. All clean technologies necessary for the power sector's decarbonization are either already mature and cost-effective (even relative to fossil fuels) or are expected to become cost-effective in the next 10 years.

The Net Zero 2060 scenario outlines a pathway in which clean energy (renewables and nuclear) grows from 9 percent of the energy mix in 2019 to 75 percent in 2060. If only market incentives are in place—no climate and clean energy policies, as under the reference scenario—clean energy's share increases from 9 percent in 2019 to merely 26 percent in 2060, with fossil fuels continuing their dominance (figure 2.4).

Figure 2.2 • Actual and projected shares of clean and fossil fuels in the primary energy mix in Europe and Central Asia under the reference and Net Zero 2060 scenarios, 2019–60



Note: Clean energy = renewables and nuclear.

Without a swift phase-down of coal, ECA cannot achieve decarbonization, because coal is the largest source of fossil fuel–based emissions in the region (excluding Russia and Belarus), representing 42 percent of all emissions. In the absence of action, coal continues to support 25–30 percent of energy use for decades to come. Under the Net Zero scenario, coal's share in the energy mix declines sharply, to below 10 percent in 2030, from over 35 percent historically. In the least-cost regional decarbonization pathway reported here, 90 percent of existing coal capacities are phased out in ECA countries by 2030, equivalent to 31 GW of coal assets being retired early by 2030, ahead of their average 40 years' useful life.

A coal phase-down is the most effective way to reach climate objectives. It also reduces the economic costs of pollution (2019 coal pollution levels would cost over US$ 120 bn in ECA by 2060), which outweigh the costs of stranded assets (based on Country Climate and Development Reports for Türkiye [World Bank 2022b] and Kazakhstan [World Bank 2022c]).

The transition away from coal is almost complete by 2040 under the Net Zero 2060 scenario, because the renewable and clean energy sources (solar, wind, hydro, bioenergy, and nuclear supported by flexible power system resources) replacing coal are already cost-effective within this time frame. On the Net Zero 2060 pathway, solar energy use grows fivefold by 2030, wind energy use nearly doubles by 2030, nuclear use doubles by 2035, and bioenergy use doubles by 2050.

For ECA to reach net zero by 2060, less cost-competitive and less mature technologies must develop further and offer higher degrees of certainty beyond 2035. Such technologies include green hydrogen, blue hydrogen, and carbon removal technologies (including bioenergy with CCS and direct air capture[16]) on the supply side and hydrogen-using technologies in transport (hydrogen fuel cell trucks, aircraft) and industry (green steel) on the demand side. The share of these technologies in the future energy mix is uncertain. Hydrogen (hydrogen, ammonia, and methanol are referred to as hydrogen derivatives in this report, or hydrogen) and synthetic fuels accounts for 10–13 percent of final consumption at different sensitivities. The role of gas depends on the success of the scale-up, efficiency, and the commercialization of CCS technologies for power and industry. CCS technologies of higher efficiency[17] can also increase blue hydrogen production in the Russian Federation and other gas-producing economies. Because of these

---

16 Direct air capture (DAC) represents the final carbon removal technology when all other options have been exploited. As such, it is placeholder for carbon removal technologies as yet unknown. DAC results in a high-cost and high-investment estimate for the removal of the remaining carbon in 2060, a conservative approach. Governments may decide to apply carbon removal not related to the energy system instead of DAC, such as forest sinks, when available and feasible. Forest sinks and forest management were not within the scope of this analysis.

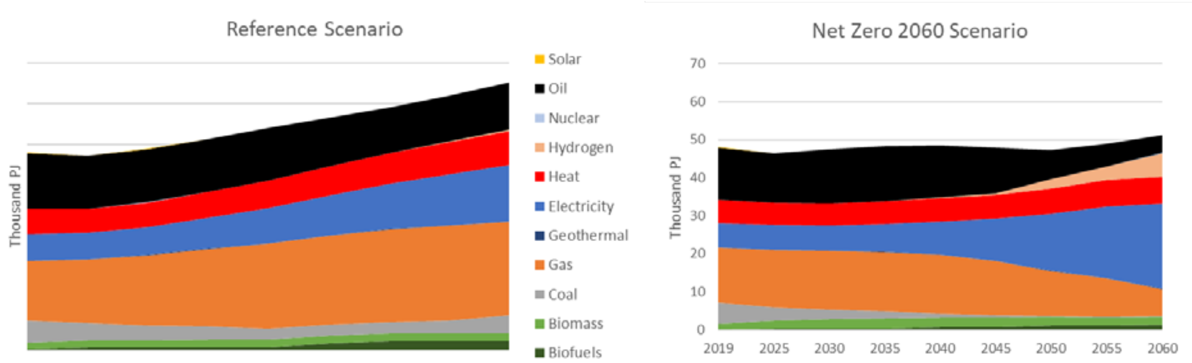
17 The assumption of CCS capture rate is up to 95 percent in the Net Zero Scenario, post-2035.

uncertainties the analysis must be revisited and updated at least every five years to reflect technological change, learning curves, and efficiency and cost improvements.

Regarding end use, electrification is the single most important step toward a more productive net zero energy system. The share of electricity in the energy mix almost triples by 2060 as heating, transport, and certain industrial processes are increasingly electrified, rising from 16 percent in 2019 to 47 percent by 2060.

On the demand side, energy efficiency, technological advances, and behavioral change save 28 percent of final energy consumption in ECA by 2060 compared with the reference scenario (figure 2.5). However, under the reference scenario, 15 percent of energy is already saved by significant energy efficiency investments that are cost-effective even in the absence of emission-related constraints. (This means that, in total, energy efficiency saves more than 40 percent of energy consumption by 2060.) Energy efficiency is one of the key measures that keeps energy consumption in check in the face of growing need for electricity; it also helps reduce the unpredictability of energy bills during the transition.

Figure 2.3 • Projected final energy consumption in Europe and Central Asia under the reference and Net Zero 2060 scenarios, by fuel type



Note: NGL = natural gas liquids.

Decarbonization is critical to ensuring sustainable growth and energy security in ECA while creating new opportunities for green industries and sectors. Following a green growth pathway can reduce fossil fuel imports, which lowers the bills of importing countries. For instance, following the green growth pathway would help Türkiye save $146 billion and Uzbekistan $67 billion by 2060 (World Bank 2022b, 2023b). Decarbonization can also help safeguard the vulnerable by stabilizing or lowering monthly household energy bills, if energy tariff reforms are complemented with investments in building renovations and more efficient technologies to reduce energy consumption.[18]

To summarize, **beyond a better climate and health outcome and pollution reduction, decarbonization can bring the following benefits:**

- greater energy security (by reducing dependence on fossil fuel imports, while increasing electricity trade, and power system resilience with advanced technologies)
- greater competitiveness (through energy efficiency, innovation, and productivity improvement)
- stable and cost reflective energy bills (through full cost recovery and energy efficiency)
- job creation (in new green markets).

18 The removal of fossil fuel subsidies in certain ECA countries could drive up energy prices for some end users in the short term.

The energy transition is expected to result in net job creation globally, as job losses in fossil fuel industries are more than offset by gains in renewables and other energy transition technologies (IRENA 2022b).[19] However, net impacts vary strongly by country and region, as recent evidence from the World Bank's Country Climate and Development Reports shows (World Bank 2022b, 2022c). Between 2019 and 2022, clean energy employment grew by 15 percent and now represents around half of the energy employment in most regions of the world (IEA 2022e), while fossil fuel–related jobs decreased by 4 percent.

The expansion of renewable energy and energy efficiency in the region should lead to a large increase in demand for labor, particularly related to the installation of wind turbines, solar PV modules, and heat pumps. In the Net Zero 2060 Scenario for ECA, employment in renewable energy generation could grow from around 200,000 job-years currently to more than 900,000 by 2040. Installation-related jobs (75 percent of the job additions in the period 2026–30) are mostly temporary, but the continuous deployment of these technologies over extended periods of time, as envisioned under a net zero scenario, provides significant opportunities for low- to medium-skilled workers. Appendix 1 presents the methodology behind these model projections.

While installation and operations and maintenance can be performed by the local workforce, manufacturing of renewable energy equipment remains very concentrated in East Asia, suggesting fewer job opportunities for ECA. East Asia currently dominates solar panel manufacturing, while Denmark, the United States, Spain, Germany, and China lead in wind turbine manufacturing, but there may exist some opportunities in several ECA countries to manufacture less complex components such as wind towers or balance-of-system hardware (wirings, interconnection). One major exception in the ECA region is Türkiye, which relatively quickly rose to become the fourth-largest manufacturer of solar panels in the world behind China, Vietnam, and the Republic of Korea. Türkiye also announced in January 2022 that it will begin to produce wind turbines domestically (World Energy 2022).

On a net zero pathway, ECA employment in energy efficiency (including heat pumps) could easily grow from the tens of thousands to more than 100,000 or even 200,000 by 2040. On average in ECA, most of the job creation would likely be in installation, operation, and maintenance. A skilled workforce will also be critical for the heat pump rollout. Current experience with the scale-up of heat pumps in Central Europe and the United Kingdom shows that a shortage of installers can slow down the transition. One positive example is Poland, which commenced domestic manufacturing of heat pumps and, according to the Polish Heatpump Association, is not facing a shortage of installers (EHPA 2023). Industry and government in the country have been active in developing vocational training courses.

* * *

The balance of this second part of the report describes in detail how the region can become carbon neutral by 2060 at the lowest cost. It considers the profound effect of recent events on energy security in the region by representing energy trade on the basis of fossil fuel pipeline flows and capacities as of May 2023 and under a stress test. This novel analysis delivers insights not covered by previous work.

---

19 Between 2022 and 2030 it is estimated that a net zero pathway would create 30 million jobs, while job losses amount to some 13 million, a net gain of 17 million (IEA 2022e).

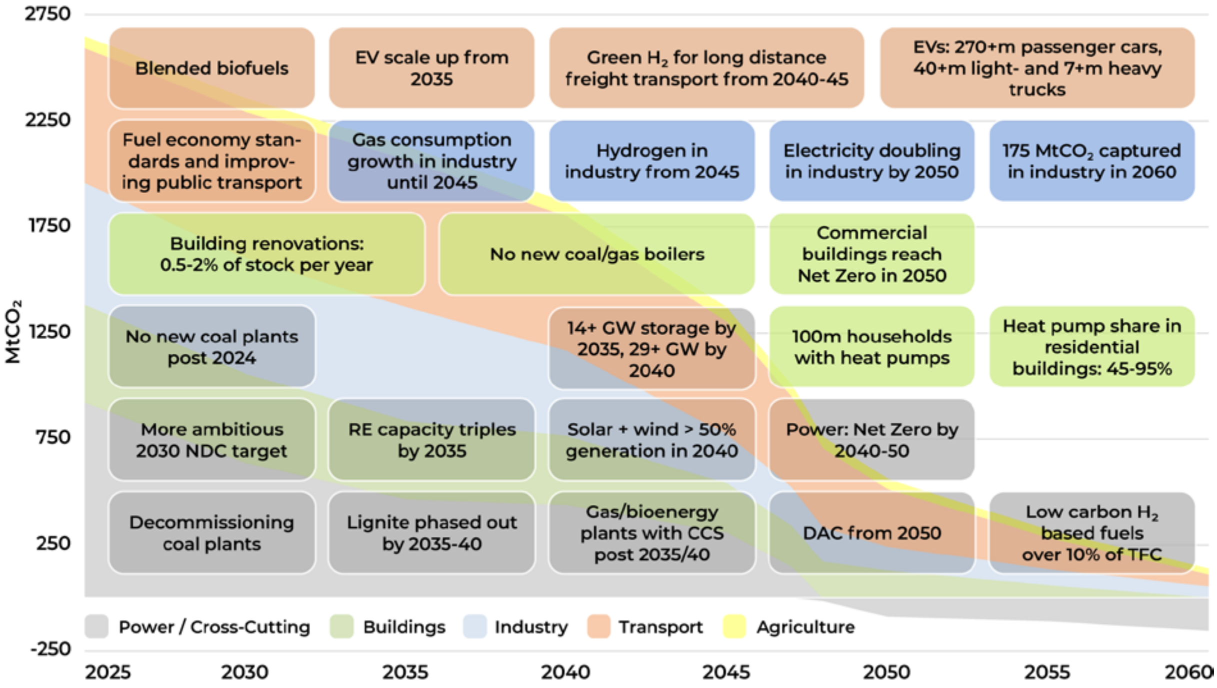
WHAT DOES IT TAKE TO DECARBONIZE THE REGION?

Without more and new targeted measures, only a fraction of required investments will flow into low-carbon technologies. Insufficient clean energy investment means that the ECA region could miss out on the opportunities the energy transition offers. Most of the investments in the net zero pathway will be from the private sector (60–90 percent of all investments), as technologies mature and costs decline. These investments can provide economic stimulus for ECA countries.

Additional policies will be needed to support decarbonization (figure 2.4). These include the following:

- National programs (policies, financing, incentives, and outreach)
- Sectoral decarbonization strategies (including net zero targets)
- Bans and phase-outs of fossil technologies
- Targets for renewable energy, hydrogen, and carbon capture and storage (CCS)
- Dedicated funding for key clean technologies, such as heat pumps and electric vehicles
- Energy-efficiency targets for the whole economy and within sectors
- Innovation funds; R&D incentives
- Talent and skill development programs for clean technologies
- Reforms of subsidies; tariff- and network-regulations
- Electricity markets
- Emissions trading systems; carbon markets
- Institutional and governance reforms.

Figure 2.4 • Energy sector milestones on the pathway to Net Zero Energy 2060 in Europe and Central Asia region



Existing consumption subsidies for fossil fuels in ECA are especially harmful, because they incentivize wasteful fossil fuel consumption and diminish the effectiveness of demand-side measures to reduce energy use and switch to cleaner alternatives. Energy subsidies also entail significant fiscal costs and create distortions across the economy (World Bank forthcoming). Consequently, to avoid distortion from the economically optimal pathway, the model used in this report assumes no fossil fuel subsidies from 2025.

Timely decisions driven by data and analytics, backed by collaborative, inclusive, and dynamic institutions and governance, are needed to ensure that the energy transition benefits the ECA economies. This is so because an increasingly complex power system centered on clean energy, storage, electricity networks, real time trade, and demand response requires new and very different capacities from key institutions. (World Bank forthcoming).

Demand-side measures are particularly pertinent in the context of increased energy system electrification, which presents opportunities for the demand side to play a greater role in the energy system as energy-using technologies become deployable as flexible assets. ECA countries need to carefully assess their circumstances to determine the right mix of enabling measures to unlock greater carbon reduction potentials while maintaining economic growth and social cohesion.

Some $4.7 trillion in investment (about 3.9 percent of GDP) is needed between 2023 and 2060 if the region is to reach Net Zero 2060 (table 2.1). This figure is $872 billion (an equivalent of 0.7 percent of GDP) higher than in the reference scenario. The estimate of additional investment needed lies at the lower end of the previous 23 CCDRs, which ranged from 1 percent (for upper-middle-income countries) to 10 percent of GDP (for lower-income countries). The lower figure here reflects the siting of renewable energy operations where costs are lowest, higher capacity factors within subregions, and greater regional collaboration and trade.

Table 2.1 • Projected investment needs in Europe and Central Asia in the reference and Net Zero 2060 scenarios, by sector

	Reference	Net Zero 2060	**Additional:** Net Zero 2060 minus reference
Transport	1,408	1,500	92
Buildings (residential and commercial)	1,245	1,293	48
Electricity sector (including transmission connections for renewables and storage)	399	953	554
Industry including hydrogen, CCS and DAC	246	347	100
Energy trade (cross-border gas and electricity lines)	65	148	83
Energy transformation	431	426	-5
Total	**3,794**	**4,666**	**872**
% of GDP	*3.14%*	*3.86%*	*0.72%*

Total investments encompass all technologies involved in the energy system value chain, including the fossil fuel, power, hydrogen, and end-use sectors (buildings, industry, and transport). These investments cover machinery, appliances, commercial vehicles, public transport vehicles (including both conventional and electric vehicles), boilers and heat pumps, and energy efficiency upgrades in building (including new windows, doors, insulation). They will create economic opportunities. They will require a conducive environment, as well as a mix of public and private funds, with foreign direct investment playing an important role in financing, innovation, and transfer of know-how.

The largest share of the additional decarbonization investments is required in the power sector, where the Net Zero 2060 investments ($934 billion) are $535 billion higher than in the reference scenario. The additional investments are required to meet surging power demand driven by economic growth, electrification of heating, transport, and industry through new power generation capacities, renewable energy transmission connections, and storage required for a much larger power sector than in the reference case.

Significant additional investments will be required to scale up and modernize electricity transmission and distribution networks, as these investments in the region have been chronically low, due to financing issues and low-cost recovery levels of utilities.[20] According to the International Energy Agency, “to meet national climate targets, grid investment needs to nearly double by 2030 to over $600 billion per year after over a decade of stagnation at the global level, with emphasis on digitalizing and modernizing distribution grids” (IEA 2023a).

Under both the reference and Net Zero 2060 scenarios, over $1.2 trillion must be invested in renovations to residential building and appliances. In the Net Zero scenario, the same heating and cooling comfort levels are achieved at much lower operating costs, as these investments reduce energy demand compared with the reference scenario. The energy efficiency investments in the Net Zero 2060 scenario result in lower household energy consumption, making energy more affordable and reducing household energy bills.

The transport sector needs the most investment, over $1.4 trillion in the ECA region under both scenarios. This includes some infrastructure updates[21] and the cost of commercial and public transport vehicles, such as buses and heavy trucks. Broader transport system costs also include consumer spending

---

20 Total transmission and distribution investment needs were not assessed in this report.

21 The transport investment estimate does not fully account for the investments needed to induce the modal shift to public transport.

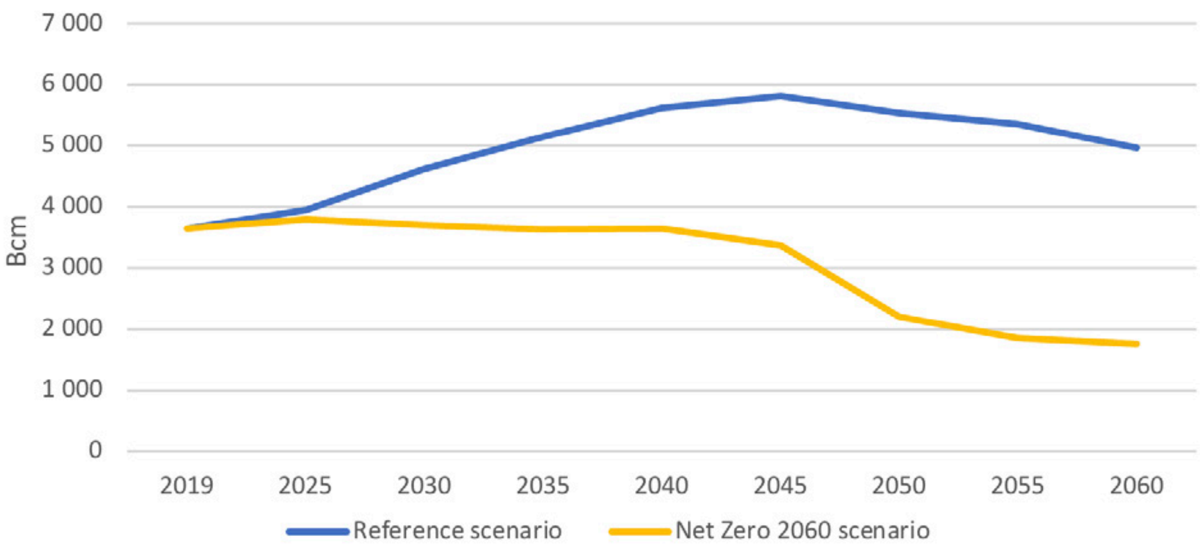
in excess of $4 trillion for light-duty vehicles over the 2060 time horizon. (The latter investments are chiefly for private consumption and are not considered investments in national accounts.)

Cross-border gas and electricity trade and the decarbonization of industry add more than $180 billion to the Net Zero 2060 pathway's investment needs. Cross-border trade flourishes in the Net Zero 2060 scenario, with an additional $83 billion of investments, reaching $148 billion. Investments in a net zero energy industry are nearly 30 percent higher at $347 billion.

TRANSFORMING THE REGION'S GAS SECTOR

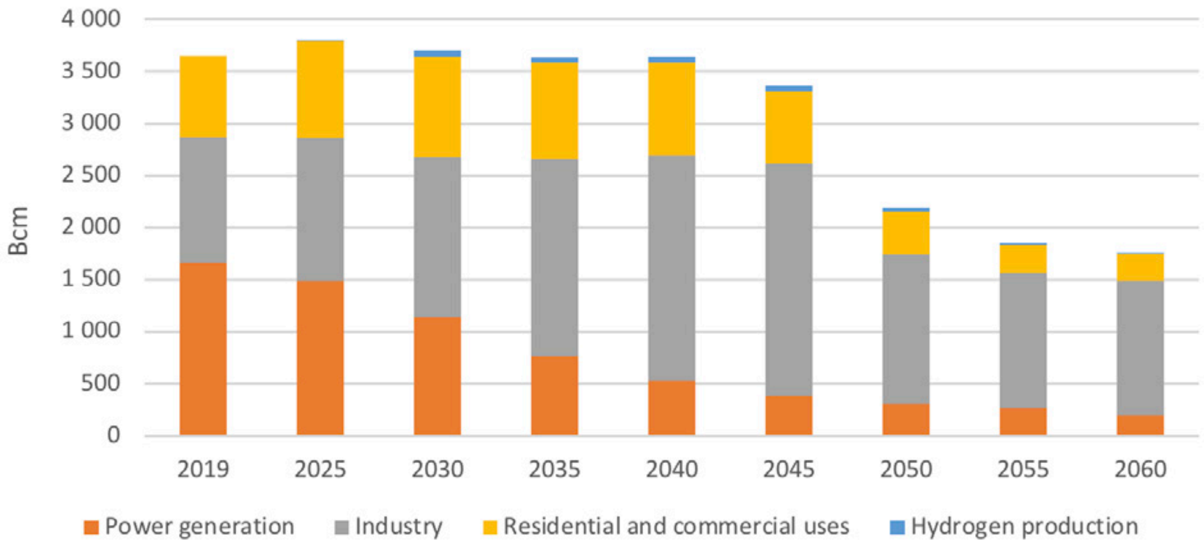
The net zero transition reduces global demand for gas by more than 3,000 billion cubic meters (bcm) by 2060 compared with the baseline. Total natural gas consumption, which was around 3,700 bcm in 2019, is projected to peak at over 5,800 bcm (60 percent higher) in 2045, declining only gradually (to around 5,000 bcm) by 2060, under the World Bank's global reference scenario. This trajectory lies in sharp contrast with the one projected under the Net Zero 2060 pathway, which indicates a much lower global demand peak before 2030, followed by a very substantial decline in subsequent decades. Projected gas consumption in 2060 (at under 1,800 bcm) is less than half the 2019 level and more than 3,000 bcm (65 percent) lower than 2060 gas demand under the reference scenario (figure 2.5).

Figure 2.5 • Actual and projected global consumption of natural gas under the reference and Net Zero 2060 scenarios, 2019–60



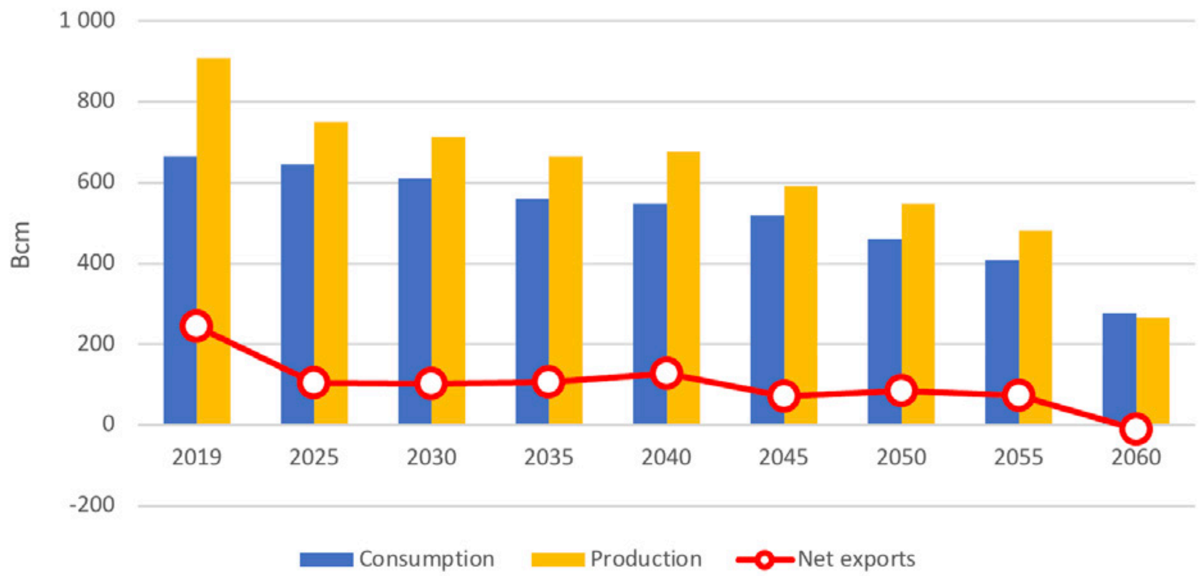
Globally, gas use for power generation and buildings sees the steepest declines in a net zero transition. In contrast, gas use in industry remains strong (with support from CCS). Blue hydrogen production contributes only marginally to global gas demand through 2060. Thanks to the rapid deployment of cleaner alternatives—predominantly solar and wind in power and heat pumps, renewable electricity, and energy efficiency improvements in household applications—natural gas use could shrink by 90 percent in the electricity sector and by two-thirds in the residential and commercial sector between 2019 and 2060 under the Net Zero 2060 scenario. Industrial demand holds up—with projections for 2060 that are about 10 percent higher than 2019 levels—thanks to the continuing increase in economic activity and sustained demand for gas-based chemical products throughout the forecast period. The contribution of blue hydrogen production to global natural gas use remains modest, given the superior economics of green hydrogen pathways in the second half of the forecast period. The contribution of blue hydrogen is greatest between 2030 and 2050 (figure 2.6).

Figure 2.6 • Actual and projected global consumption of natural gas under the World Bank's Net Zero 2060 scenario, by sector, 2019–60



In the ECA region, gas production is projected to drop more rapidly than consumption under the Net Zero scenario, eroding the region's traditional gas surplus over time.[22] The drop in gas production is driven predominantly by Russia's permanent loss of its European export market after 2022. Central Asia—where key legacy producers (particularly Uzbekistan and Kazakhstan) have struggled to maintain gas output levels in recent years—will also contribute to the region's production decline. Although it is facing an imminent production squeeze, the ECA region moves more slowly on reducing gas demand under the Net Zero 2060 scenario. As a result, total net exports from the ECA region could drop below zero by 2060, from a surplus of over 240 bcm in 2019 (figure 2.7).

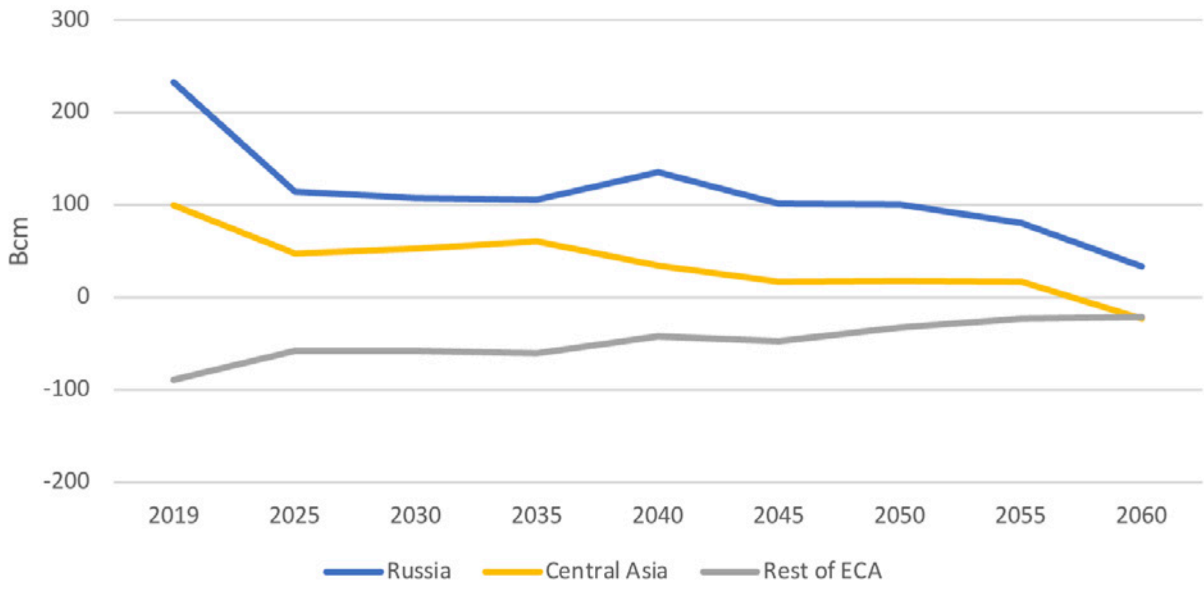
Figure 2.7 • Actual and projected production, consumption, and trade balance in Europe and Central Asia under the World Bank's Net Zero 2060 scenario, 2019–60



22 Because of the ongoing conflict between Russia and Ukraine, the natural gas production and consumption pathway (as well as the outlook for hydrogen production and exports) is subject to a very high degree of uncertainty.

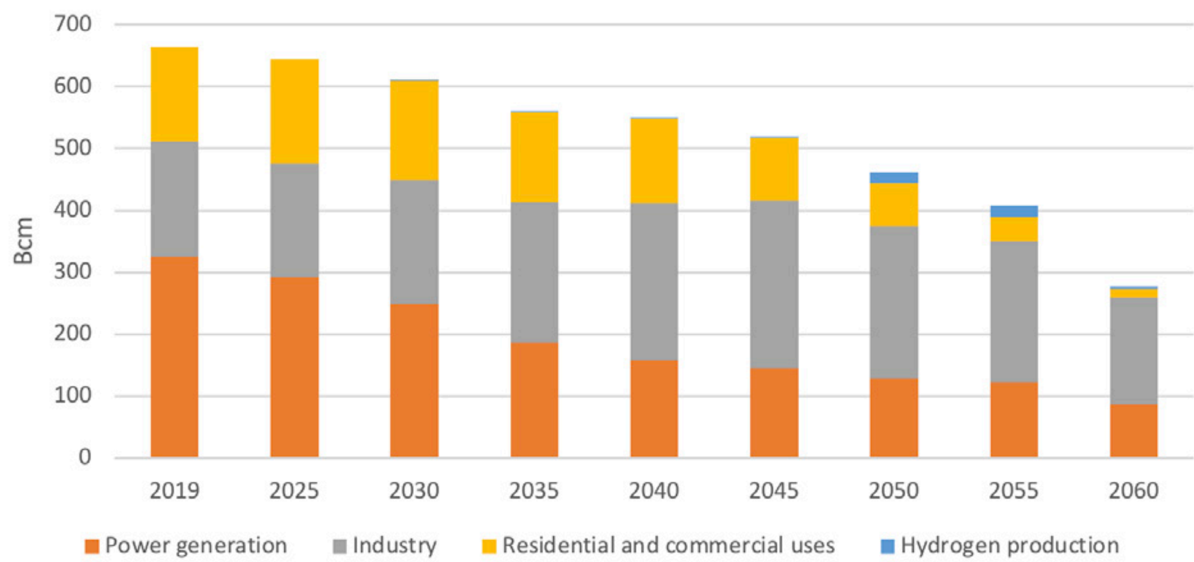
Russia and Central Asia see substantial decreases in their natural gas surplus. Russia's net exports of gas shrink by 85 percent, and Central Asia turns from a sizable net exporter to a net importer of gas by 2060. The rest of the region reduces its net natural gas deficit by around 75 percent by 2060, thanks to the rapid deployment of low-carbon alternatives (figure 2.8).

Figure 2.8 • Actual and projected net export balance in Europe and Central Asia under the World Bank's Net Zero 2060 scenario, 2019–60



Gas consumption in the region drops sharply, especially after 2050, thanks to lower demand in power generation and residential and commercial uses. The widespread deployment of building retrofits, heat pumps, and the electrification of cooking and water heating can all but eliminate gas use in the residential and commercial sector by 2060 under the Net Zero 2060 scenario (figure 2.9). Gas for power demand also comes under pressure across the region, thanks to the sustained rollout of renewables (as well as nuclear power in some countries, including Russia and Türkiye). Gas consumption in the industrial sector stays robust throughout the forecast period, enabled partly by the at-scale deployment of carbon capture, usage, and storage (CCUS) under the Net Zero 2060 scenario. After 2050, blue hydrogen production also contributes to the gas demand mix, driven almost entirely by Russia, which accounts for more than 90 percent of the region's gas use for hydrogen production between 2050 and 2060.

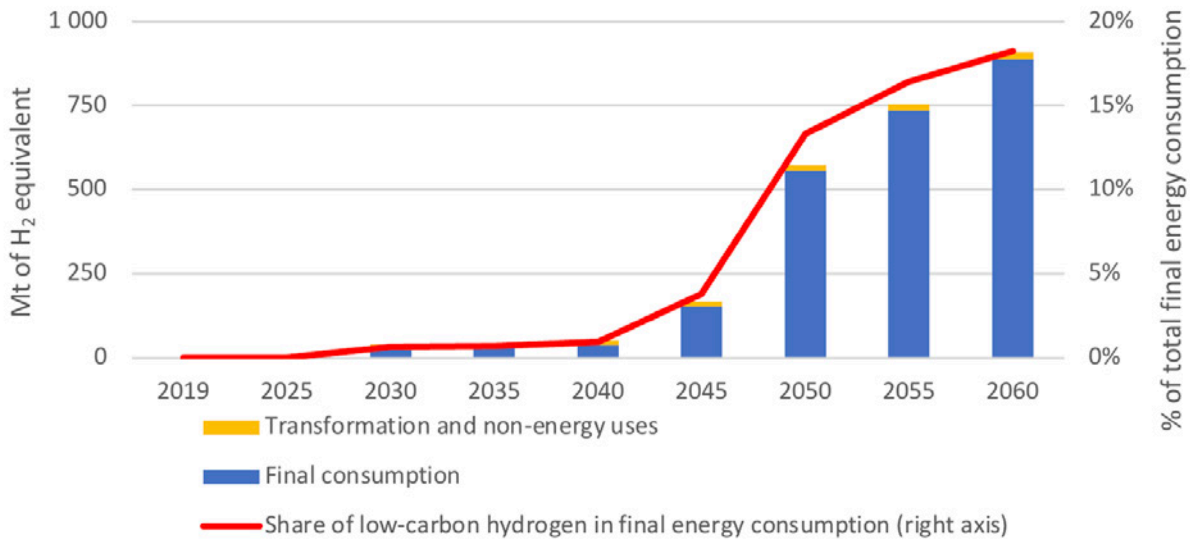
Figure 2.9 • Actual and projected consumption of natural gas in Europe and Central Asia under the World Bank's Net Zero 2060 scenario, by sector, 2019–60



DEVELOPING A HYDROGEN SECTOR

The rapid deployment of low-carbon hydrogen based fuels— technologies yet to be commercially cost-competitive—is a key component of most net zero scenarios, including the International Energy Agency's Net Zero by 2050 scenario and the World Bank's Net Zero 2060 pathway.[23] Under the World Bank's Net Zero scenario, the global share of low-carbon hydrogen-based fuels, including green ammonia and methanol, grows from negligible levels today to 13 percent of final energy consumption by 2050 (figure 2.10).

Figure 2.10 • Actual and projected global consumption of low-carbon hydrogen and share of total final energy consumption under the World Bank's Net Zero 2060 scenario, 2019–60



Such growth may appear exceedingly ambitious, but low-carbon hydrogen projects have enjoyed substantial momentum in recent years, thanks to the large-scale investment incentives provided by the Inflation Reduction Act in the United States and the REPowerEU plan in the European Union. The proliferation of net zero commitments and national hydrogen strategies in a wide range of countries and the growing role of international financial institutions in supporting green hydrogen projects in developing countries are fueling investor interest in low-carbon hydrogen projects around the world (box 2.1). The use of hydrogen to produce low-carbon fertilizer in Central Asia is discussed in detail in appendix 3.

23 Low-carbon hydrogen includes hydrogen volumes derived from water electrolysis, fossil fuels with CCUS, and biogenic sources.

Box 2.1 • World Bank Group support of green hydrogen projects in Poland and Chile

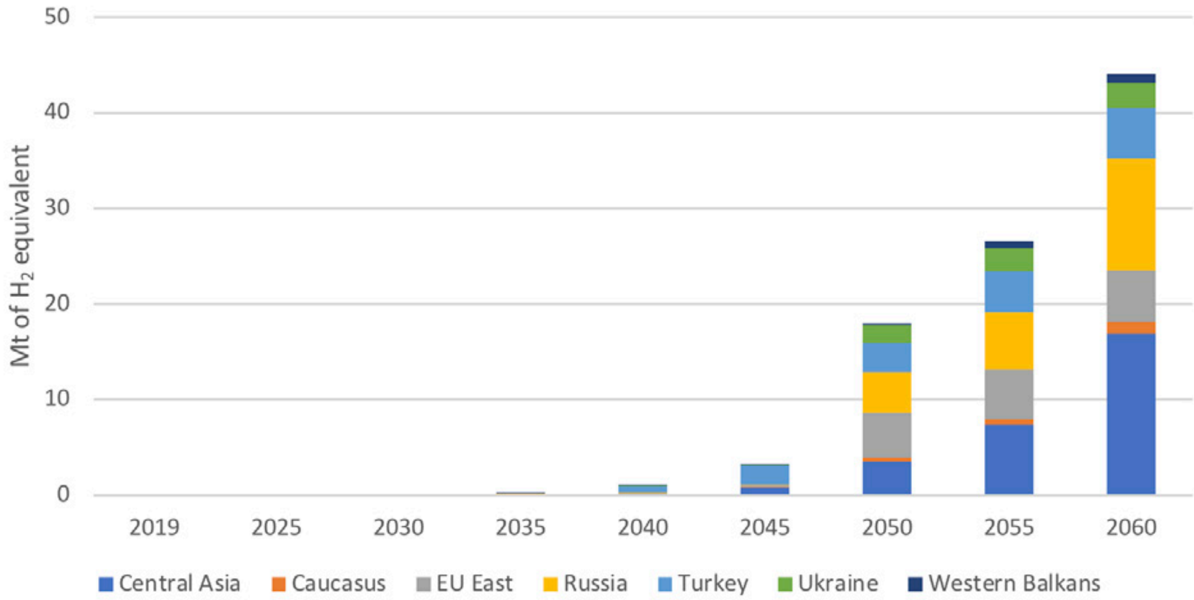
In June 2023, the International Finance Corporation (IFC) concluded a cooperation agreement with Polenergia, an energy developer listed on the Warsaw Stock Exchange, for the development of a green hydrogen pilot project in Poland. The scope of the pilot—part of a larger 110 MW green hydrogen scheme—includes the construction of a 5 MW electrolyzer, two hydrogen refueling stations, and associated infrastructure at the H2HUB Nowa Sarzyna project site. As part of the cooperation agreement, IFC will provide pre-investment support to refinance the initial development cost of the project and cover 50 percent of the purchase price of the electrolyzer for the pilot scheme. IFC pre-investment support was deemed necessary for Polenergia to de-risk the project and be able to reach financial closure in 2023. IFC obtained the right of first offer to provide up to €35 million of financing for the 5 MW pilot, which is expected to close in Q4 2023, as well as to participate in the debt financing of the larger 110 MW green hydrogen project following successful implementation of the pilot scheme.

Poland is one of the largest consumers of gray hydrogen in Europe, with annual demand exceeding 1 million tonnes in the industrial sector. Green hydrogen projects such as H2HUB Nowa Sarzyna form an essential part of Poland's energy transition strategy and will contribute to meeting the growing demand for low-carbon hydrogen in line with the European Union's REPowerEU plan. Collaboration on the development of green hydrogen in Poland is well-aligned with IFC's Green Hydrogen Strategy and the climate change strategy of IFC in Europe.

Within weeks of the IFC announcement, the World Bank approved a $150 million facility to support investments in green hydrogen projects in Chile. The loan will establish a blended finance fund for green hydrogen projects and develop risk mitigation instruments to improve investor confidence. The World Bank will also provide technical assistance to build local capacity and demand for green hydrogen development. This sustainable financing mechanism can be used to channel resources from other multilateral and climate finance institutions as well as from the private sector. The announcement marks the World Bank's first-ever loan to promote green hydrogen in support of climate change mitigation efforts. Its innovative blended finance and risk mitigation mechanism is intended to be replicated in other World Bank partner countries and target regions over time.

Low-carbon hydrogen starts to take off only after 2040 under the World Bank's Net Zero 2060 scenario in ECA. Despite the strong policy push to accelerate the deployment of clean hydrogen in some advanced economies around the world—and irrespective of the significant production potential in certain ECA subregions—without subsidies the economics of low-carbon hydrogen production are expected to remain challenging for at least another two decades. The eventual rollout of clean hydrogen production toward the end of the forecast period is dominated by Central Asia and Russia, which together account for two-thirds of clean hydrogen supply within the ECA region in 2060 (figure 2.11).

Figure 2.11 • Actual and projected production of low-carbon hydrogen in Europe and Central Asia under the World Bank's Net Zero 2060 scenario, 2019–60



Note: In the figure, "Russia" refers to the subregion of Russian Federation and Belarus.

In 2060, low-carbon hydrogen production in the region is projected to be dominated by green hydrogen (hydrogen produced through electrolysis); blue hydrogen (hydrogen produced using fossil fuels with CCUS) makes inroads only in Russia (figure 2.12). In the World Bank's Net Zero 2060 pathway, green hydrogen emerges as the predominant hydrogen production pathway across the region, thanks to the highly favorable economics of renewables-based electrolysis in the second half of the forecast period. Russia experiences significant growth in blue hydrogen production, particularly between 2045 and 2055, thanks to its abundant low-cost natural resources and potential CO_2 storage sites. By 2060, however, the superior economics of green hydrogen overshadows blue hydrogen even in Russia. Consequently, hydrogen produced from fossil fuels with CCUS constitutes less than 3 percent of the region's low-carbon hydrogen production by 2060.

Even if fully implemented, the clean hydrogen project pipeline would cover only a small fraction of the long-term capacity needed to meet net zero goals. This gap reflects high costs and uncertainties.[24] Although rapidly expanding, current proposals for low-carbon hydrogen projects across the region fall well short of the long-term requirements under the World Bank's Net Zero 2060 pathway (figure 2.13). The sum of all projects under construction, proposed, or speculated on yields clean hydrogen production capacity of only about 3.8 Mt—and more than half of this capacity (2 Mt) is attributable to a single megaproject in Kazakhstan, which is currently at the conceptual stage. These figures are dwarfed by the projected supply of about 18 Mt by 2050 and 44 Mt by 2060, underscoring the need for policy frameworks and incentives that encourage not only the timely implementation of projects in the pipeline but also the multiplication of proposed clean hydrogen schemes on the drawing board within the next decade or two.

24 It bears repeating that clean hydrogen is yet to become commercially cost-competitive.

Figure 2.12 • Projected production of low-carbon hydrogen from electrolysis and from fossil fuels with carbon capture, usage, and storage in Europe and Central Asia in 2060 under the World Bank's Net Zero 2060 scenario, by subregion

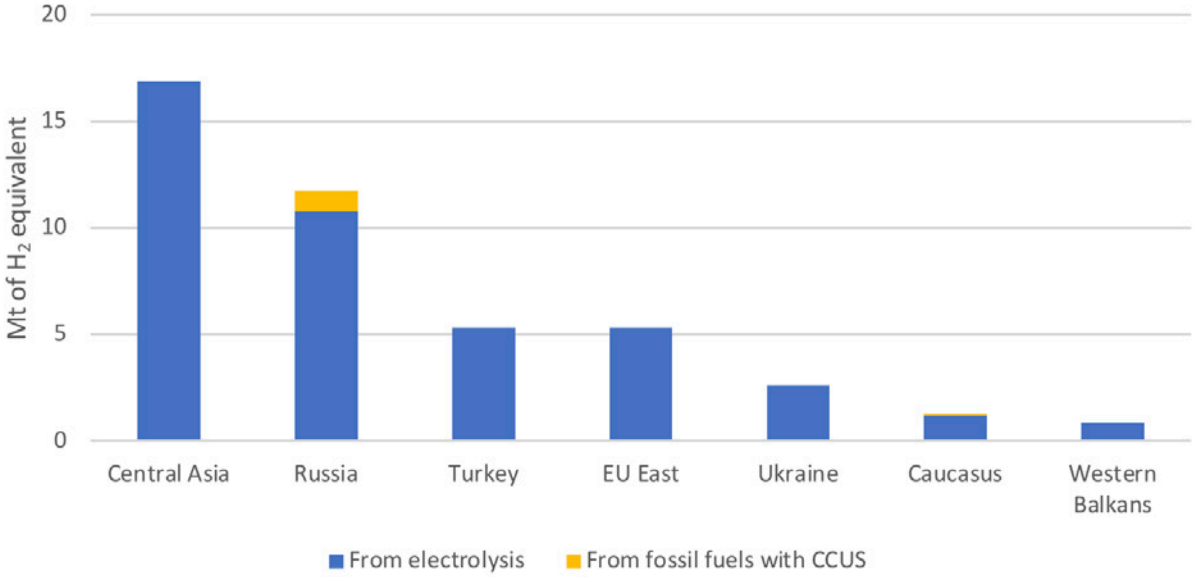
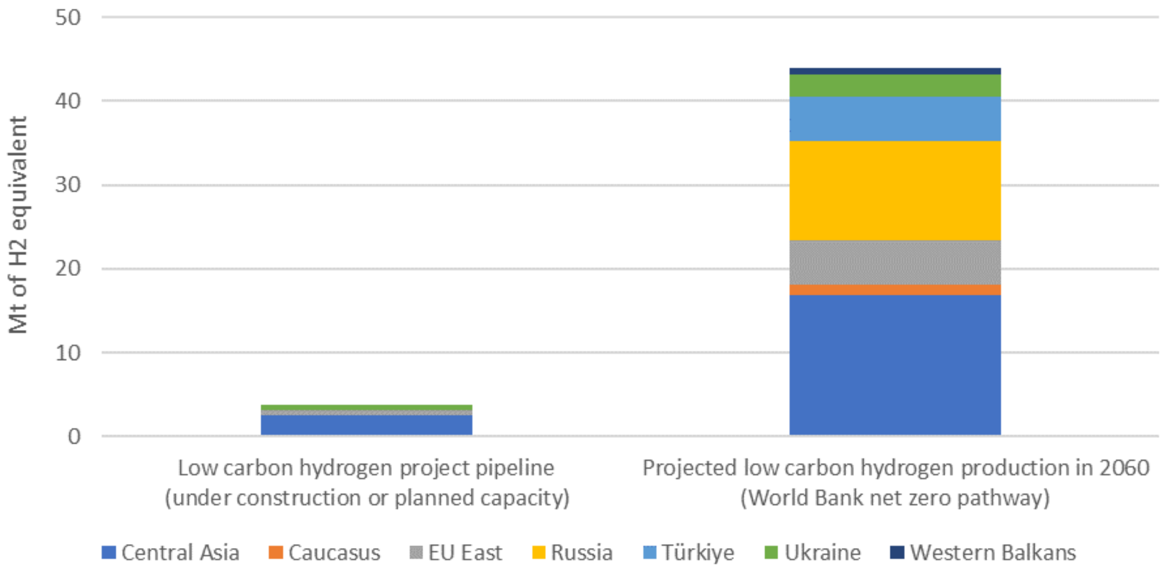
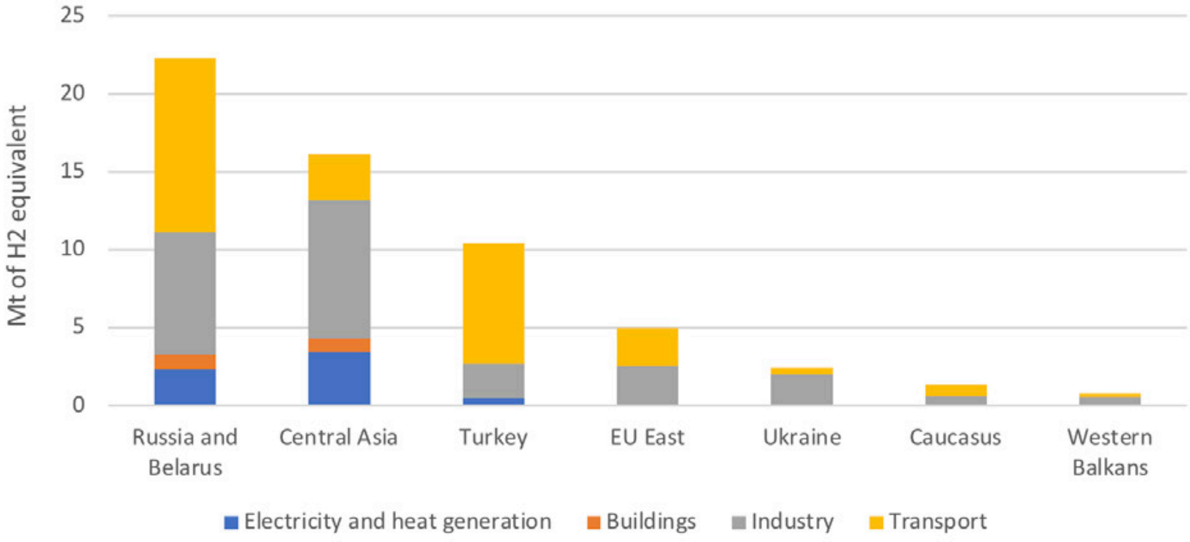


Figure 2.13 • Project pipeline in 2023 and projected production of low-carbon hydrogen in 2060 in Europe and Central Asia under the World Bank's Net Zero 2060 scenario, by subregion



Clean hydrogen could account for 10–13 percent of final energy consumption in ECA by 2060, depending on the development of two main end-use markets: transport and industry. By 2060, the two sectors are projected to account for 44 percent and 42 percent of clean hydrogen deployment, respectively, under the Net Zero 2060 scenario. Clean hydrogen gains ground in these applications, thanks to the lack of scalable alternatives to decarbonize hard-to-abate sectors, which include long-distance heavy-duty transport and the manufacturing of steel, cement, and chemicals, among others. In a sensitivity test in which it is assumed that long-distance heavy-duty road transport becomes fully electric, hydrogen accounts for only 10 percent of final consumption in ECA. In Russia (plus Belarus) and Central Asia—the two leading ECA subregions for clean hydrogen uptake—hydrogen is also projected to be used in power and heat generation by the end of the forecast horizon (figure 2.14).

Figure 2.14 • Projected use of low-carbon hydrogen sector in Europe and Central Asia in 2060 under the World Bank's Net Zero 2060 scenario, by subregion



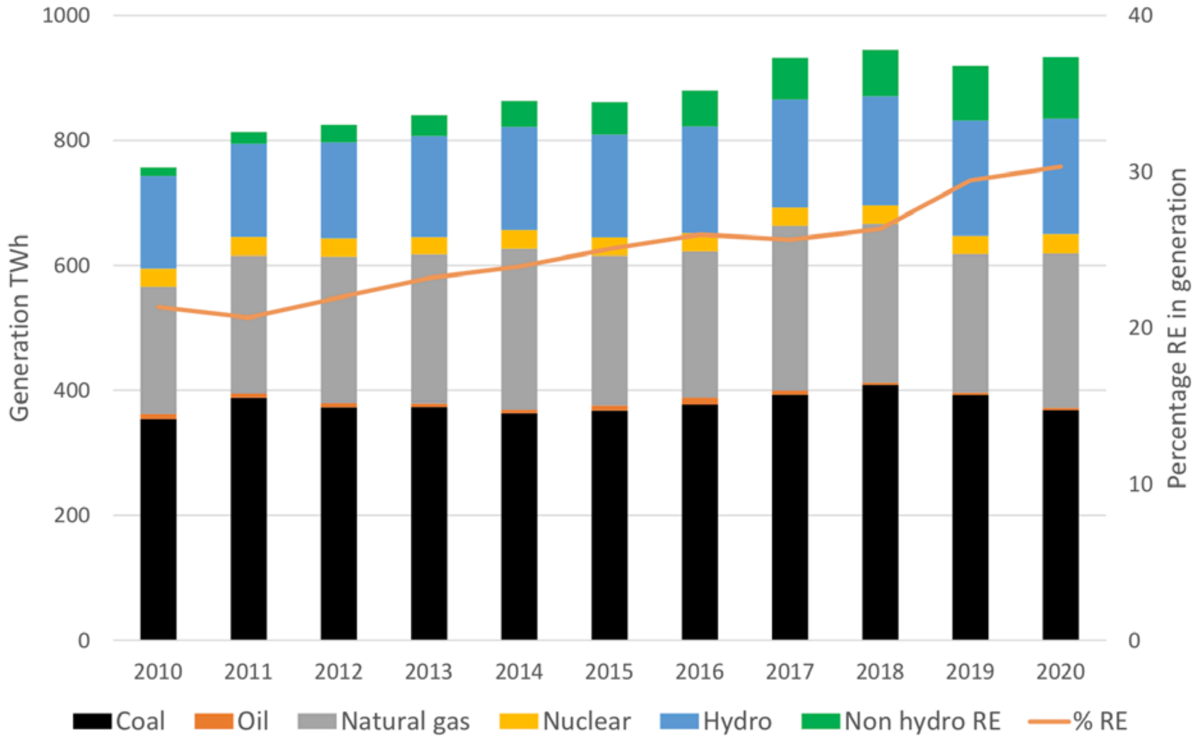
TRANSFORMING THE REGION'S POWER SECTOR

The 2022-2023 energy crises (World Bank. 2022a.) contributed to a significant shift in power production patterns in the region, with gas-based power generation declining and renewable energy sources (biomass, solar, and wind) increasing. Increasing the share of renewables, energy efficiency and improving the flexibility of the power system offer the most sustainable pathway to net zero emission while boosting economic growth.

About 58 percent of electricity generation in ECA countries currently relies on natural gas and coal. Natural gas accounted for 35 percent of total electricity generation in 2020, a far larger share than the global average of about 25 percent (figure 2.15). Coal products accounted for 28 percent of electricity generation, hydroelectric power 18 percent, and nuclear energy 14 percent. Oil products, geothermal, solar photovoltaics, and solar thermal made smaller contributions. The picture differs widely across countries, however. Coal is the largest source of power production in Bosnia and Herzegovina, Bulgaria, Kazakhstan, Kosovo, North Macedonia, Poland, Serbia, and Türkiye. Natural gas is the largest source in Armenia, Azerbaijan, Belarus, Moldova, the Russian Federation, Turkmenistan, and Uzbekistan. Hydropower accounts for most of the power generation in Albania, Croatia, Georgia, Montenegro, Romania, Tajikistan, and the Kyrgyz Republic. Nuclear leads in Ukraine (all as of 2019).

Phasing down coal is a least-cost, no-regrets action; without a coal phase-down, a low-carbon power sector in ECA is not possible. In the Net Zero scenario, lignite power plants are phased out in the ECA region starting in 2030–40, followed by the gradual phase-out of the last coal power plants. The coal phase-down is accompanied by the uptake of renewables. Several countries have already announced plans to phase out coal. They include Bulgaria (which plans to do so by 2038 or 2040), Croatia (2033), North Macedonia and Montenegro (2035), Poland (2049), and Romania (2030 or earlier).

Figure 2.15 • Aggregate trends in electricity generation for ECA countries, 2010–20



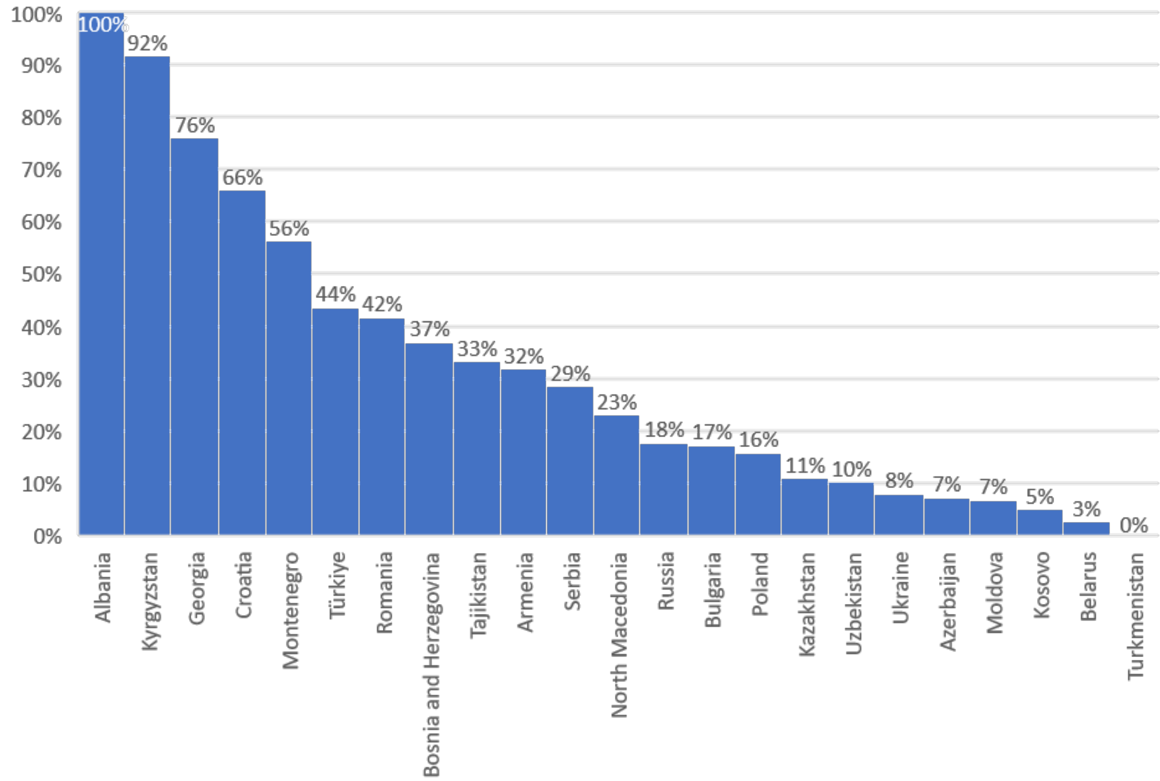
Source: IEA 2024.

On average, the ECA region generated nearly 30 percent of its power from renewable energy in 2020, mainly hydropower (over 20 percent). This share varied widely across countries, with Albania, the Kyrgyz Republic, and Tajikistan generating more than 90 percent of their power from renewable sources and Ukraine, Azerbaijan, Moldova, Kosovo, Belarus, and Turkmenistan generating less than 10 percent (figure 2.16).

Despite some progress, solar and wind potential is still largely untapped in most of the region. Generation from non-hydro renewable sources (wind, solar PV, bioenergy and geothermal) rose by more than five-fold between 2010 and 2020. In 2020 these renewables fueled more than 10 percent of total generation across the region, compared with 2.4 percent in 2010. However, generation is concentrated in seven countries with more than 1 TWh in 2020—Türkiye and the four countries that are members of the European Union, plus Kazakhstan and Serbia.

Renewable capacities need to increase by nearly 70 percent by 2030 and more than triple by 2035 in the region's power sector if the region is to reach net zero emissions by 2060 in a cost-effective manner. Most of the capacity additions are solar and wind, given excellent regional potential for these resources, although new hydro and bioenergy also increase in some locations. In the model, the share of renewables in the power mix increases from 31 percent in 2020 to 44 percent by 2030 and 84 percent by 2050.

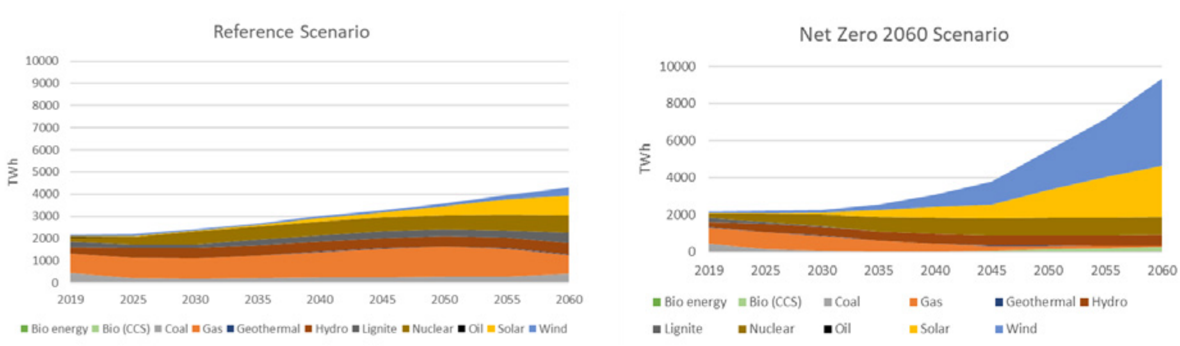
Figure 2.16 • Share of renewables in annual electricity generation in Europe and Central Asia, by country, 2019



Source: ww from the IEA World Energy Statistics and Balances (IEA 2019, 2020).

Solar and wind are the cornerstones of a low-carbon power system in ECA. By 2040, the share of solar and wind in the region reaches 53 percent in the Net Zero 2060 scenario (figure 2.17). High variability of solar and wind become key concerns for ECA governments even earlier in several subregions where solar and wind reach more than around 20–25 percent of the power mix, starting with the EU4 in 2025–30 followed by the Western Balkans and Türkiye before 2035. The pathways represent the economically optimal uptake of solar and wind and is hindered by several barriers in ECA countries.

Figure 2.17 • Actual and projected electricity generation by fuel in Europe and Central Asia under the reference and Net Zero 2060 scenarios, 2025–60



Reasons for slow solar and wind deployment across ECA include the lack of comprehensive and consistent policy portfolios, the lack of binding renewable energy targets, limited grid access, long permitting procedures, and lack of transparency. These shortcomings are reflected in relatively poor scores on the World Bank's Regulatory Indicators for Sustainable Energy[25]) (ESMAP 2023). The RISE score for the region as a whole rose from 17 in 2010 to 47 in 2021, reflecting significant progress. However, ECA remains significantly below the global average, lagging behind the Middle East and North Africa, and Latin America and the Caribbean. In a World Bank market sounding exercise, ECA market players agreed that major barriers include the lack of binding long-term development targets for renewable energy, long waits for permits, lack of grid access (waiting times of 7–15 years for transmission connectivity), lack of transparency, and other regulatory, market, financial, and policy barriers—all investigated in detail in the forthcoming World Bank report *Barriers to RE Scale Up in Europe and Central Asia* (World Bank and ESMAP forthcoming). Addressing these major barriers will be essential to speed up solar and wind deployment in the region in the years ahead.

Large shares of solar and wind are technically possible in a Net Zero 2060 scenario using multiple flexible resources, not just storage. Governments need to scale up the most cost-effective flexibility resources in parallel with the scale-up of solar and wind, to ensure secure system integration of solar and wind. Power system flexibility helps manage the variability of solar and wind power and maintain a balance between electricity supply and demand.

The importance of system flexibility for increasing the role of renewables

Growth in renewables-based generation depends on the power system's ability to absorb it, which depends on system flexibility. The components of a flexible low-carbon system fall into six groups:

- **Power plants** that can rapidly adjust their output to balance the grid, including gas-fired power plants equipped with CCS, advanced nuclear power plants, and plants using biogas or biomass.
- **Energy storage systems,** such as residential and commercial battery storage systems, EV batteries with vehicle-to-grid capabilities, and pumped hydro storage and utility-scale battery storage systems.
- **Demand-side flexibility,** centered on incentives to induce power users to lower their consumption at peak times or increase it when renewable output is high.
- **Cross-border power trade,** which connects power grids, in order to help manage the variability of renewables. Cross-border transmission lines are highly underutilized in the region, providing an opportunity to scale up trade in the short term.
- **Power-to-X** technologies, which can convert excess renewable electricity into other forms of energy, such as hydrogen-based fuels or useful products like desalinated water (power-to-water), and fertilizers. The resulting products can be stored for later use or sold to generate revenue.
- **The scaling up of electricity transmission and distribution network investments,** which is essential for a successful energy transition in ECA, as the aging networks not only pose potential security challenges but are also becoming one of the most important barriers to the scale up of renewable energy in the region, according to the *Barriers to RE Scale up in Europe and Central Asia* report (World Bank and ESMAP forthcoming). Advanced grid technologies—including smart grids (which automatically adjust to changes in power supply and demand) and energy management systems (which help industries and other large electricity consumers manage their energy use more efficiently)—are needed.

In several ECA subregions, gas with CCS (beginning in 2035) and bioenergy with CCS (beginning in 2040) could play important roles in providing dispatchable power system flexibility. CCS can be used in countries and region with abundant gas resources (such as Russia, Central Asia, and Azerbaijan) or cost-effective sustainable bioenergy resources (such as Eastern Europe, the Western Balkans, Russia, and Türkiye). Bioenergy with CCS is a carbon removal technology that offsets remaining emissions in

25 Details on the indicators can found at RISE (esmap.org)

hard to abate industry and transport sectors in several regions. Gas with CCS and bioenergy with CCS are dispatchable resources, contributing to the dispatchable power system flexibility. Power system flexibility in the region is strengthened by over 14 GW of battery storage by 2035 and over 29 GW by 2040. Power trade and demand response also contribute to power system security in the region.

Historically, energy security meant meeting energy demand with an adequate level of supply and storage, because energy demand was inflexible. In the ECA region, demand-side flexibility was especially low for certain services, such as heating, as there were no viable alternatives to fossil fuels (coal and gas) and biomass during the cold ECA winters. New technologies (including smart meters, heat pumps, storage, solar heat, demand response, and energy efficiency) have increased demand-side flexibility, energy savings, and fuel switching, improving energy security.

In May 2022, the European Commission presented the REPowerEU Plan, paving the way for similar programs globally. The plan is intended to end the European Union's dependence on Russian fossil fuels by achieving energy savings, accelerating the rollout of renewable energy, and diversifying energy supplies (European Commission 2022b).

Recent energy price shocks in Europe have highlighted the fact that scaling up investments in demand-side flexibility to improve energy security requires having the right energy price signals in place. Because of the post-pandemic recovery and the slowdown in Russian gas supplies following the invasion of Ukraine, wholesale natural gas and electricity prices in Europe skyrocketed in 2022, and still remain above long-term averages in 2023 and early 2024. Several EU countries have established energy markets with deregulated electricity and natural gas tariffs; consumers in these countries experienced significant increases in their energy bills. Higher end-user energy prices improved energy security by reducing demand during the winter of 2022, but it hurt industrial production (in 2022 and 2023) and household welfare.

These price signals (combined with the perception that energy prices will remain high for the next few years) accelerated the deployment of new technologies to reduce energy demand and switch away from fossil fuels. Sales of heat pumps in Germany increased by more than 50 percent in 2022, for example, making them the technology with the highest growth rate in the market (Clean Energy Wire 2023). Heat pump sales also reached record levels in Poland in 2022–23.

Removing barriers to demand response is the first step in increasing demand-side flexibility. Few demand-response programs or aggregators exist in the region. One of the primary barriers to the expansion of demand response is limited awareness of its benefits among end users, utilities, and policy makers. Even if the concept were better understood, demand cannot provide emergency response or balancing services unless the current rules are changed. In most countries in the region, demand is not eligible to participate in power system balancing; instead, traditional power plants provide balancing services, but at high cost. Existing pricing mechanisms and grid operation practices also hinder the use of demand response.

An example of a commercial demand response participant is Enel X in Poland, which has a demand response capacity of 546 MW. Enel X is active in the Polish capacity market and could expand further if the Polish market continues to be liberalized, allowing demand to provide more grid services. Enel X is one of the largest global players in the demand response market. It is present in 18 countries, with 9.3 GW of demand response capacity (including 6,300 e-buses, 197,000 heat pumps, and over 3 million lighting points under management), representing annual energy spending of €9.3 billion.

Weak consumer incentives limit the utility of demand-response schemes. With some of the largest energy subsidies in the world, consumers in the ECA region have little incentive to change their behavior (box 2.2). Public campaigns to promote conservation during peak times (by lowering thermostats, turning off unused lights, and avoiding using appliance that could be used at other times) would be a good way to start transforming passive consumers into proactive ones pending the introduction of monetary rewards. Putting a cost-reflective tariff system in place would encourage the entry of demand aggregators, whose role in the power system is illustrated in figure 2.18.

Box 2.2 • Delaying the transmission of energy price shocks to consumers: Good or bad?

The gas and electricity price shocks experienced in Europe starting in late 2021 have had a profound impact on household and industrial consumers. Transmission of these price shocks to consumers differed widely across countries, depending on the tariff-setting regulations and methodology.

In contrast with the European Union, many countries in ECA have regulated electricity and gas prices, which gives them more leeway to mitigate the impact of price increases in the short term. Unlike the EU countries, many ECA countries reacted to the wholesale energy price shocks by tempering their short-term transmission to consumers, hampering efforts to improve longer-term energy security. In some ECA countries, tariffs are set by a regulator or directly by the government.

When the recent global energy crisis hit, some of these countries decided to mitigate the transmission of energy price shocks to consumers, keeping tariffs constant or raising them only slightly. Doing so shielded consumers in the immediate term but put heavy burdens on fiscal budgets. These countries include Albania, Armenia, Azerbaijan, Belarus, Bulgaria, Georgia, Kosovo, the Kyrgyz Republic, Moldova, Montenegro, Tajikistan, Turkmenistan, and Uzbekistan (countries marked as "high" in table B.3.2.1). In these countries, the regulator (or often, in the absence of the regulator, the government) decides when and how to pass on (or not pass on) the impact of energy price shocks to consumers. The absence of established energy markets giving adequate price signals reduces the incentives to reduce energy demand in response to price increases, which could harm the countries' long-term energy security. This issue is exacerbated by the fact that in many ECA countries with regulated markets, energy tariffs are subsidized below cost-recovery levels.

The resources of these countries' energy state-owned enterprises cannot be maintained in the longer run, especially if wholesale energy prices remain high. This approach also prevented consumers from receiving price signals that could stimulate demand-side flexibility, in the form of reduced demand or increased investments in renewable energy and energy efficiency, thus stunting efforts to improve energy security. In the European Union, several countries, including Croatia, Poland, and Romania, have liberalized electricity and gas prices for industrial and commercial users. These users felt the price increases almost immediately. Many small businesses in these countries were forced to close temporarily or permanently, and industrial consumers had to reduce their output to limit energy consumption. In countries that have liberalized electricity and gas prices for residential consumers, households started feeling the increases in their energy bills as early as October 2022.

Table B2.2.1 • Ability to mitigate transmission of short-term price shocks to consumers in Europe and Central Asia, by country

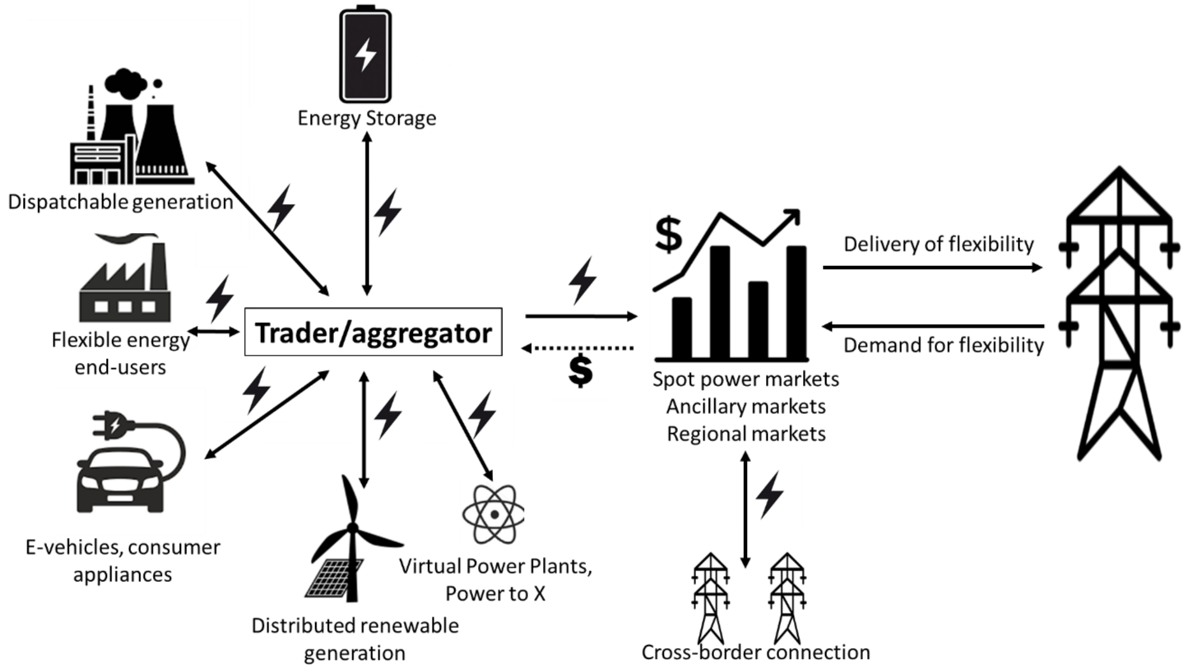
Country	Electricity tariff setting		Natural gas tariff setting		Ability to mitigate transmission of short-term price shocks to consumers consumers
	Households	Non-households (low-voltage)	Households	Non-households	
Albania	Reg.	Reg.	Reg.	Reg.	High
Armenia	Reg.	Reg.	Reg.	Reg.	High
Azerbaijan	Reg.	Reg.	Reg.	Reg.	High
Belarus	Reg.	Reg.	Reg.	Reg.	High
Bosnia and Herzegovina	Reg.	Open	Mixed	Mixed	Medium
Bulgaria	Reg.	Reg.	Reg.	Reg.	High
Croatia	Reg.	Open	Reg.	Reg.	Medium
Georgia	Reg.	Reg.	Reg.	Open	Medium
Kazakhstan	Reg.	Open	Reg.	Reg.	Medium
Kosovo	Reg.	Reg.	n.a.	n.a.	High
Kyrgyz Rep.	Reg.	Reg.	Reg.	Reg.	High
Moldova	Reg.	Reg.	Reg.	Reg.	High
Montenegro	Reg.	Reg.	n.a.	n.a.	High
North Macedonia	Reg.	Reg.	Open	Open	Low
Poland	Reg.	Open	Reg.	Open	Low
Romania	Open	Open	Open	Open	Low
Russian Fed.	Reg.	Open	Reg.	Reg.	Medium
Serbia	Reg.	Reg.	Reg.	Open	Medium
Tajikistan	Reg.	Reg.	Reg.	Reg.	High
Türkiye	Mixed	Open	Open	Open	Low
Turkmenistan	Reg.	Reg.	Reg.	Reg.	High
Ukraine	Reg.	Open	Open	Open	Low
Uzbekistan	Reg.	Reg.	Reg.	Reg.	High

Note: Reg. = Regulated tariffs, Open = Liberalized tariffs. Low: Open market pricing for households of electricity and/or gas. Medium: Open market pricing for non-household consumers of electricity and/or gas. High: Fully regulated electricity and gas markets. n.a. Not applicable

Implementing a demand response program depends on real-time communication among the assets under management, which requires smart meters and reliable 24/7 data connections. The requisite digital infrastructure is not in place in all countries in the region, few of the region's system operators publish the real-time condition of the grid, and utilities do not provide real-time price signals for demand-side action.

Demand response also relies on collecting energy consumption data from consumers. Concerns about data privacy, security, and ownership can pose barriers to demand response programs. Addressing these concerns and establishing robust data protection measures are crucial for building trust among consumers.

Figure 2.18 • Flexible electricity system resources and the role of demand aggregators



The combined effect of better demand response and heightened production of green hydrogen

Improving demand response and green hydrogen production can reduce the need for large-scale storage (mainly batteries) and lower the cost of the energy transition. An illustrative example shows that under the Net Zero 2060 scenario, peak demand in Central Asia in 2050 can be shifted to the daytime by encouraging energy end use (such as aggregated EVs or industry) and enabling hydrogen production during peak solar generation hours. Green hydrogen production in the power sector can contribute to the use of curtailed electricity during times of high solar and wind generation, providing important balancing options in ECA power systems after 2035–40. Battery storage and hydro storage, wind, and conventional generation (with CCS) can cover the traditional evening peak, when solar generation is unavailable.

The role of regional power exchanges for energy security

The role of electricity in energy security is set to increase in ECA via electrification of end uses that increase the share of electricity in the energy mix from 16 percent in 2019 to 47 percent by 2060 under the Net Zero 2060 scenario. Electrification also presents a growth opportunity for the power system, as the power sector is projected to be nearly twice as large in 2060 under the Net Zero 2060 as in the reference scenario. As energy efficiency and end-user electrification continue to advance and variable renewable generation grows, the operating environment in the region is becoming more dynamic and tied to real time.

Electricity security depends on the power system's ability to "ensure uninterrupted availability of electricity by withstanding and recovering from disturbances and contingencies" (IEA 2020). Those disturbances include the following:

- **Inherent system risks,** such as large shares of variable renewables, limitations of availability or capacity in transmission and distribution networks, and technical failures
- **Commercial risks** related to markets, contracts, prices, and financing
- **External risks,** such as cyberthreats, geopolitical events, policies, regulations, macroeconomic risks, and extreme weather events.

These risks are addressed at various levels of the power sector value chain and in several market segments. Beyond the aforementioned technology options, well-functioning electricity markets play a critical role in ensuring electricity security by balancing supply and demand, providing transparent price signals, increasing competition and efficiency, and offering flexibility to both generators and consumers. Well-functioning electricity markets however require availability of infrastructure, including cross-border and domestic transmission and distribution networks equipped with up-to-date automation and data connectivity, which have yet to be introduced or updated in several ECA countries. Infrastructure bottlenecks can limit the effectiveness and efficiency of existing electricity markets.

Twelve spot power exchanges already facilitate day-ahead and intraday trading of electricity in the region, improving short-term security (table 2.2). Day-ahead markets manage trade via auctions; they typically offer products that are based on hours of the day. Tradable contracts correspond to the 24 delivery hours of the following day. Intraday power trading can be continuous or auction based; it allows for trading in quarter-hour or one-hour intervals, with the ability to trade up to 30 minutes before delivery. This flexibility in intraday trading intervals allows market participants to manage their power procurement and sale risks, thereby reducing system balancing needs.

Table 2.2 • Day-ahead, intra-day, and futures markets of power exchanges in Europe and Central Asia, by country

Country	Power exchange	Electricity markets		
		Day-ahead	Intra-day	Futures
Albania	ALPEX	✔		
Armenia				
Azerbaijan				
Bosnia and Herzegovina				
Bulgaria	IBEX	✔	✔	
	EEX			✔
Croatia	CROPEX	✔	✔	
	EEX			✔
Georgia	GEMEX	✔	✔	
Kazakhstan	KOREM	✔	✔	✔
Kosovo	ALPEX			
Kyrgyz Republic				
Moldova				
Montenegro	MEPX	✔		
North Macedonia	MEMO	✔		
Poland	TGE	✔	✔	✔
	EPEX Spot	✔		
	EEX			✔
Romania	OPCOM	✔	✔	✔
	EEX			✔
Serbia	SEEPEX	✔	✔	
	EEX			✔
Tajikistan				
Türkiye	EPIAS	✔	✔	✔
Turkmenistan				
Ukraine	UEEX	✔	✔	✔
Uzbekistan				

Ten futures power markets in ECA already help reduce commercial risks through futures and forward contracts. "Cash-settled" contracts make it possible to buy or sell a specific volume of gas or electricity at a predetermined price for settlement on a specific future date. Market participants (including generators, consumers, and retailers) use these markets to hedge against price risks. Trades can be executed on the exchange or over the counter.

In the nine countries participating in the European Energy Community—the six Western Balkan countries, Georgia, Ukraine, and Moldova—efforts toward regional market integration are accelerating. Coordinated auction offices for capacity allocation and spot power exchanges (such as ALPEX for Albania and SEEPEX for Serbia) have been established. With the adoption of an ambitious legislative package in December 2022, European regional market integration became legally binding: Contracting parties must adopt the EU body of pertinent law permitting full integration of their electricity markets with the rest of Europe. Contracting parties were supposed to have transpose the EU package into national legislation by the end of 2023, but delays are expected. Technical and operational implementation of the package would create a pan-European integrated market, further enhancing electricity security in the region.

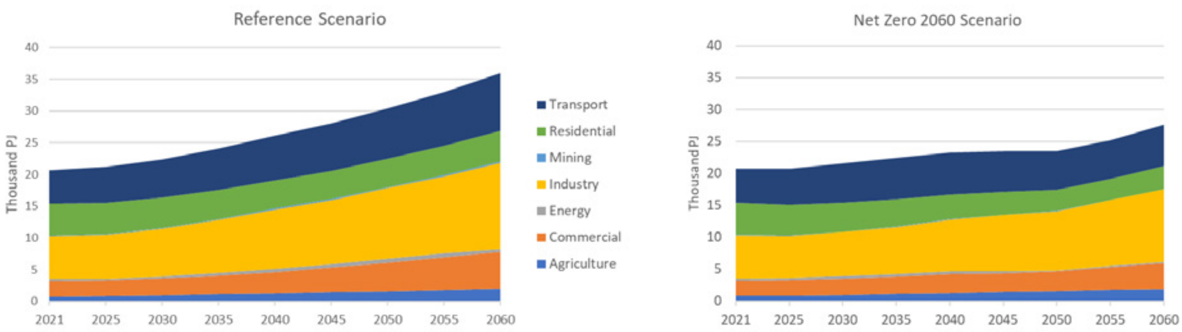
In Central Asia and the South Caucasus, only Georgia and Kazakhstan have power exchanges. Other countries are dominated by local incumbents and operate under a model in which the incumbent manages all power trading relations. The Central Asia Power System—in which Kazakhstan, the Kyrgyz Republic, and Uzbekistan operate in a synchronized mode—presents an opportunity for broader market integration through market coupling following the establishment of spot power exchanges. Coupling would permit the exploitation of local renewable generation assets at a regional level, providing a new way to manage outages. Historically, the region has seen shortages in the winter. In 2022, the entire Central Asian grid collapsed, leading to blackouts throughout large parts of Uzbekistan, Kazakhstan, and the Kyrgyz Republic. In January 2023, a week of near-freezing temperatures led to widespread outages in Uzbekistan.

In the short term, there is room to improve and rethink electricity security definitions, emergency response procedures, and related measurements and indicators throughout the region. In many countries, contingency plans for short-term electricity shortages could be established or improved, along with prioritized interruption plans and demand-side flexibility arrangements. The growing share of variable renewables makes it necessary to find new and better ways to ensure a reliable and resilient power system.

TRANSFORMING ENERGY USE IN THE TRANSPORT, BUILDINGS, AND INDUSTRIAL SECTORS

Energy efficiency has an important dampening effect on total final energy consumption (TFC) by sectors in the World Bank's Net Zero 2060 scenario, signaling expected improvements in energy intensity.[26] In 2060, TFC is projected to be 28 percent lower in the Net Zero 2060 scenario than in the reference scenario (figure 2.19). The effect of energy efficiency is especially apparent in the commercial and residential building sector. Between 2021 and 2060, building sector TFC increases by 30 percent in the reference scenario and by just 2 percent in the Net Zero 2060 scenario. In the transport sector, TFC increases by 42 percent in the reference scenario and 18 percent in the Net Zero 2060 scenario. Industry sees the strongest TFC growth in both scenarios, increasing by 56 percent in the reference scenario and 51 percent in the Net Zero 2060 scenario.

Figure 2.19 • Actual and projected total final energy consumption in Europe and Central Asia (excluding Russia and Belarus) under the reference and Net Zero 2060 scenarios, by sector, 2021–60



In the Net Zero 2060 scenario, industry accounts for the largest share of TFC in the ECA region in 2060, at over 12,600 petajoules (PJ), followed by buildings (just over 7,500 PJ), transport (around 6,500 PJ), and agriculture (just over 2,000 PJ). Projections differ widely across subregions and countries. In Türkiye,

26 Energy intensity—the energy required to deliver one unit of GDP—is high in the ECA region. In Belarus, Central Asia, and Russia, it is around twice as high as the global average and three times the EU average; in the Caucasus and the EU4 countries, it is close to or below world averages.

Poland, the Baltics, and Eastern Europe, for example, the transport sector accounts for the largest share of TFC throughout the period, reflecting strong projected economic growth and resulting vehicle uptake. Central Asia has the highest projected overall increase, a reflection of significant projected GDP growth there.

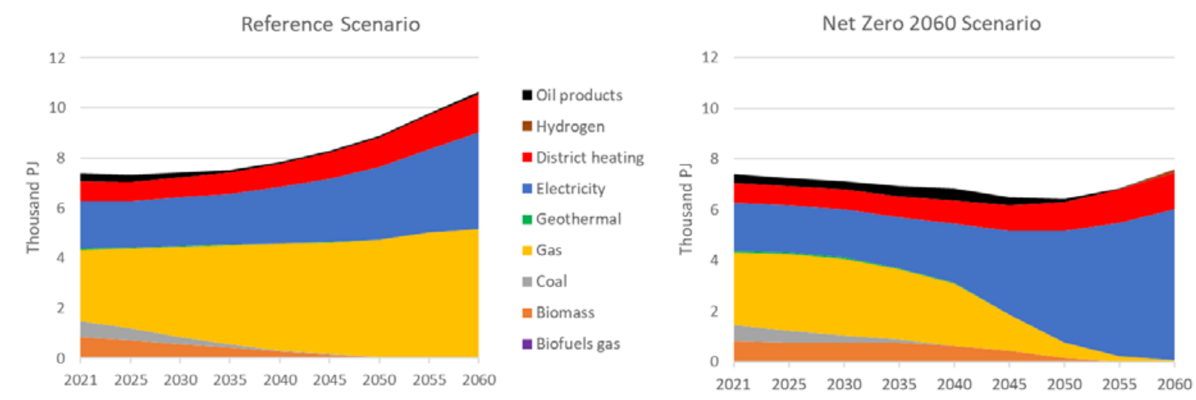
Grid electricity plays a dominant or increasingly important role in all sectors in the Net Zero 2060 scenario. It is projected to account for 78 percent of TFC in buildings, 52 percent in industry, and 44 percent in transport in 2060. Hydrogen enters the mix in industry and transport beginning in 2050; it accounts for 17 percent and 27 percent of sectoral TFC, respectively, by 2060.

Buildings

Buildings are the second sector after the power sector to reach complete decarbonization in 2050 (commercial buildings) and 2055 (residential buildings), at regional level. Tightening energy and carbon performance requirements for the construction and operation of buildings combined with electrification of heating and the integration of renewable energy, EVs, and battery storage technologies drive the strong uptake of grid electricity.

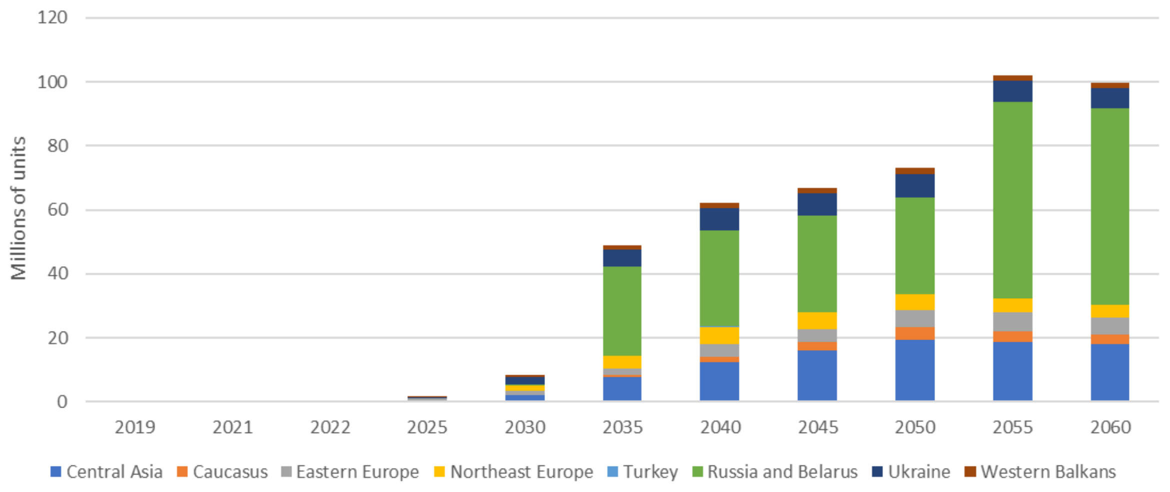
Buildings emissions are the first to decline across all end use sectors. For the region excluding Russia, building sector emissions drop by 9 percent, from 246 $MtCO_2$/year in 2019 to 225 $MtCO_2$/year in 2030 (figure 2.20). By 2040, emissions from buildings drop by nearly 30 percent in the Net Zero 2060 scenario before declining to just 2 percent in 2060. By 2060, the share of heat (discussed in the spotlight on district heating in appendix 2) in TFC by buildings increases from 11 percent in 2021 to 19 percent in the Net Zero 2060 scenario.

Figure 2.20 • Actual and projected total final energy consumption by buildings in Europe and Central Asia (excluding Russia and Belarus) under the reference and Net Zero 2060 scenarios, by fuel type, 2021–60



Heat pumps are a key technology for buildings. From a base of only about 250,000 heat pumps in 2019 and limited market penetration through 2030, strong uptake is projected in the Net Zero 2060 scenario, peaking at over 100 million households (61 million in Russia alone) with heat pumps in 2050. Growth in residential heat pumps is expected to be especially high from 2030 (figure 2.21). The electrification of heat is driven by declining heat pump unit costs as result of economies of scale and strong growth in global supply chains with adoption of this highly efficient technology. Targeted incentives and possible bans or phase-outs of coal and gas boilers can further speed up the deployment of sustainable heating practices, but bans and subsidies are not assumed in the analysis. Several countries, including Australia, France, Ireland, the Netherlands, and the United Kingdom, have adopted such bans.

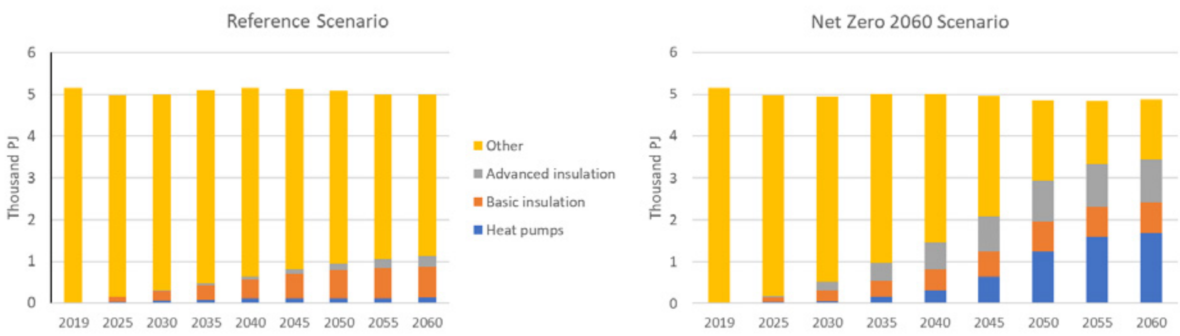
Figure 2.21 • Actual and projected number of residential heat pumps in Europe and Central Asia under the World Bank's Net Zero 2060 scenario, by subregion, 2019–60



Demand for residential space heating could be reduced by 15 percent with basic insulation measures in both the reference and Net Zero 2060 scenarios. Even without strong carbon price signals, basic insulation measures, such as replacing windows, progressively offset demand for heating in residential dwellings, which falls from 2 percent of TFC in 2025 to 15 percent of TFC by 2060, in both the reference and Net Zero 2060 scenarios.

In the Net Zero 2060 scenario, heat pumps provide 35 percent of residential space heating demand by 2060, driven by strong carbon signals and a shift away from gas in the power system. By 2060, more advanced insulation measures (upgrading building envelopes), reduce demand by 21 percent in the Net Zero 2060 scenario, and 5 percent in the reference scenario (figure 2.22). Heating systems (such as gas boilers and district heating systems), account for a 77 percent of TFC by 2060 in the reference scenario and 29 percent in the Net Zero 2060 scenario. The uptake of insulation and heat pumps varies widely across the region. In Türkiye and the Caucasus, where residential heating is based primarily on individual systems (e.g., gas boilers and biomass), heat pumps provide the lion's share of heating services by 2060 in the Net Zero 2060 scenario.

Figure 2.22 • Actual and projected uptake of insulation measures and heat pumps in Europe and Central Asia under the reference and Net Zero 2060 scenarios, 2019–60



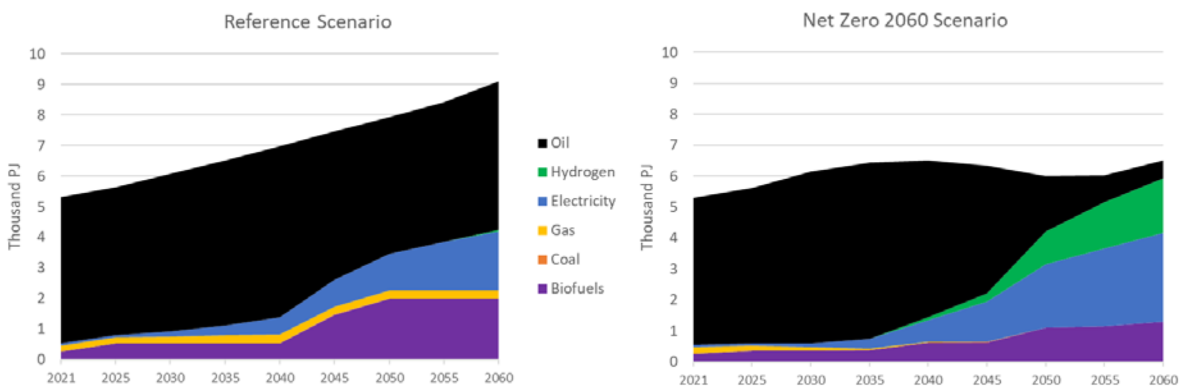
Note: "Other" refers to remaining heating demand based on existing systems (e.g., gas boilers and district heat). Basic insulation measures can include upgrades of windows, doors, lighting, and appliances; advanced measures include deeper building retrofits.

Transport

Biofuels and EVs are mature technologies that can be deployed now in the ECA transport sector. Biofuels and electrification both increase gradually in the Net Zero 2060 scenario, as the share of grid electricity in TFC grows from 1 percent in 2021 to 44 percent by 2060, with two- and three-wheelers, cars, buses, and passenger trains nearly fully electric by 2060 (figure 2.23). The share of EV in road freight transport is also high. Natural gas is fully phased out in transport, but oil maintains a 9 percent share in the Net Zero 2060 scenario by 2060, as a result of its continued use in aviation, trucking, and shipping, the subsectors hardest to abate.

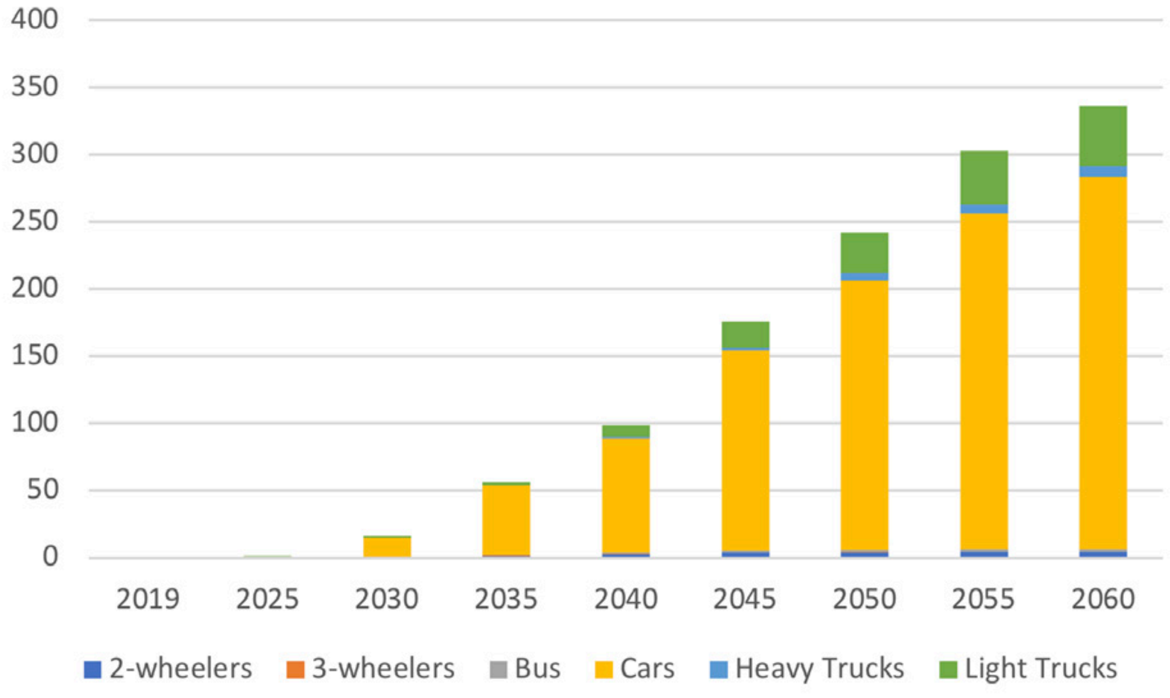
Low-carbon hydrogen-based fuels are set to play a role in the decarbonization of aviation and shipping, while their role in long-haul road freight is subject to greater uncertainty. By 2060 the transport sector can become a major user of hydrogen-based fuels (including ammonia and methanol), using 44 percent of the hydrogen in ECA. Clean hydrogen is bound to gain ground in transport because of the lack of scalable alternatives to decarbonize hard-to-abate long-distance transport (including aviation, shipping, and long-haul road freight transport). In a sensitivity where long-distance heavy trucks go fully electric hydrogen accounts to a lower share (10 percent of total final consumption) in ECA compared to 13 percent of total final consumption in the Net Zero 2060 scenario, where the share of electric trucks is high but not close to 100 percent.

Figure 2.23 • Actual and projected total final energy consumption in the transport sector in Europe and Central Asia (excluding Russia and Belarus) under the reference and Net Zero 2060 scenarios, 2021–60



Fast growth in the number of EVs, beginning in 2035, drives electrification of transport in the Net Zero 2060 scenario, creating a market for over 300 million EVs. The new EV market includes approximately 270 million passenger cars, 44 million light trucks, 7 million heavy trucks, and 2 million buses (figure 2.24). Targeted incentives for EVs, significant investments in grid and charging infrastructures, and bans or phase-outs of internal combustion engines are among the key enabling measures driving the electrification of transport.

Figure 2.24 • Actual and projected number of electric vehicles in Europe and Central Asia under the World Bank's Net Zero 2060 scenario, by vehicle type, million vehicles, 2019–60



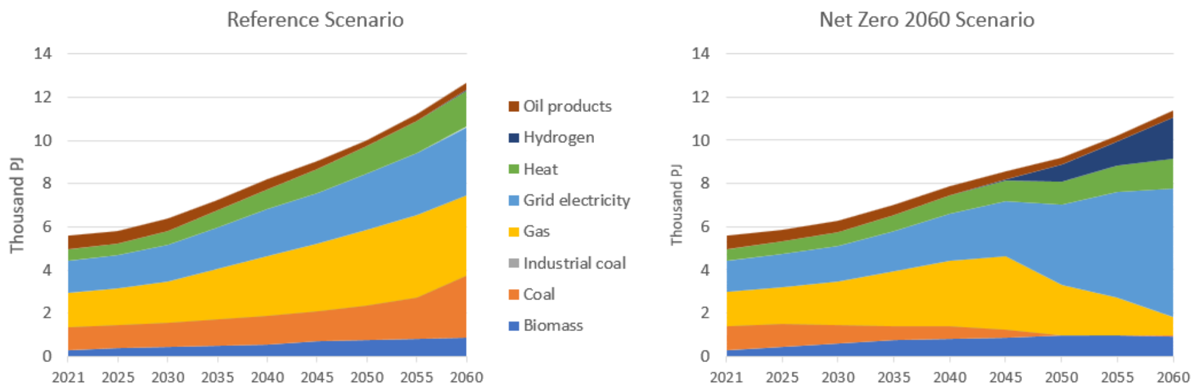
Fuel switching in the Net Zero 2060 scenario happens in in combination with a shift to more public transport and vehicles that comply with more ambitious fuel efficiency standards. A share of urban passenger transport shifts to public alternatives including 2–3 wheelers and buses (2 million electric buses by 2060) in the Net Zero 2060 scenario. A fully electrified rail sector provides an opportunity to move more passengers and freight from roads to rails, reducing costs while saving energy consumption and reducing carbon emissions.

Industry

Industry is the hardest sector to decarbonize in the Net Zero 2060 scenario. In the first decade of the scenario, coal is replaced not by electricity but by biomass and gas, as many industry sectors cannot yet be electrified. Later electrification starts to play a role, as the share of grid electricity in TFC more than doubles, to 52 percent by 2060. Finally, hydrogen and CCS come into play by 2045 (figure 2.25). By 2060 industry can become a major user of hydrogen-based fuels including ammonia and methanol, using 42 percent of hydrogen's share of TFC as clean hydrogen gains ground in manufacturing of steel, fertilizers, cement, and chemicals, among others.

With economic growth and increasing industrial activity, industry emissions swell in the Net Zero 2060 scenario to a maximum of nearly 250 $MtCO_2$/year by 2040 before dropping to just over 75 $MtCO_2$/year in 2060, a reduction of more than 75 percent compared with 2021. Residual industry emissions in 2060 are captured by CCS technologies, which come online between 2045 and 2050.

Figure 2.25 • Actual and projected final energy consumption of industry sector in Europe and Central Asia under the reference and Net Zero 2060 scenarios, by fuel type, 2021–60



Enabling measures are essential to drive efficiencies and decarbonization in industry. They include the following:

- Promotion of energy management systems such as ISO 50001
- Capacity building and training for industrial energy auditors and managers, and for clean technology deployment and innovation
- Programmatic deployment of efficient green technologies such as motors, pumps, and drives
- Targeted R&D incentives
- Use of automation, software, robotics, and artificial intelligence.

Parts of the region may also experience structural changes as their economies industrialize, while others may shift away from a reliance on heavy industry for GDP growth toward manufacturing, light-industries, and services. Governments could promote such changes to reduce the energy intensity of industry.

Fertilizer production is an important chemical sector in many ECA countries, one in which green alternatives will become increasingly cost-effective in the face of climate change, geopolitical risks, and volatile gas prices. Agriculture plays a fundamental role in most ECA countries, and fertilizer use is set to increase in the upcoming decades across the region, particularly in Central Asia, where the increase is driven by growing demand for food for a growing population and growing economies. The use of green hydrogen to produce low-carbon fertilizer in Central Asia is discussed in detail in appendix 3. In the green fertilizer analysis, green ammonia production from solar power becomes cost-competitive with gray ammonia as early as 2030 and 2035, first in Kazakhstan then in Uzbekistan, in a calculation where Net Zero 2060 gas prices and shadow carbon prices are applied.

REFERENCES

Abnett, Kate. 2023. “EU to Extend Emergency Gas Price Cap for Another Year.” Reuters, December 19. https://www.reuters.com/business/energy/eu-extend-emergency-gas-price-cap-another-year-2023-12-19/.

Bloomberg. 2023. “Turkey Gas Field Opening Sets Stage for Pre-Election Energy Giveaway.” Bloomberg, April 17, 2023. https://www.bloomberg.com/news/articles/2023-04-17/turkey-sakarya-gas-field-opening-sets-stage-for-pre-election-energy-giveaway.

Bloomberg News. 2024. “Russia Sees Its Natural Gas Exports Recovering on Higher Shipments to China.” January 25. https://www.bloomberg.com/news/articles/2024-01-25/russia-sees-its-natural-gas-exports-recovering-on-higher-shipments-to-china

BP. 2022. *BP Statistical Review of World Energy 2022*. 71st ed. London: BP. https://www.bp.com/content/dam/bp/business-sites/en/global/corporate/pdfs/energy-economics/statistical-review/bp-stats-review-2022-full-report.pdf.

Christiaensen, L., C. Ferré, M. Honorati, T. J. Gajderowicz, and S. M. Wrona. 2022. “Towards a Just Coal Transition Labor Market Challenges and People’s Perspectives from Wielkopolska.” World Bank, Washington, DC. https://elibrary.worldbank.org/doi/epdf/10.1596/38175.

Christiaensen, L., and C. Ferré. 2020. “Just Coal Transition in Western Macedonia, Greece: Insights from the Labor Market.” Jobs Working Paper 54, World Bank, Washington, DC.

Clean Energy Wire. 2023. “Heat Pump Sales in Germany Jump 53 Percent in 2022.” Clean Energy Wire, January 18, 2023. https://www.cleanenergywire.org/news/heat-pump-sales-germany-jump-53-percent-2022.

EHPA (European Heat Pump Association). 2023. EHPA and Renewable Heating and Cooling. 2021. *Strategic Research and Innovation Agenda for Heat Pumps*. Brussels: Renewable Heating and Cooling. https://www.ehpa.org/wp-content/uploads/2023/07/RHC-ETIP-SRIA-HPs-2021v02-WEB.pdf.

ENTSOG (European Network of Transmission System Operators for Gas). 2023. “ENTSOG Transparency Platform.” https://transparency.entsog.eu/#/map.

ESMAP (Energy Sector Management Assistance Program). 2023. “Regulatory Indicators for Sustainable Energy (RISE) (database).” https://rise.esmap.org/.

ESMAP. N.d. “About REZoning.” https://rezoning.energydata.info/about.

Eurasianet. 2023. “Kazakhstan: Officials Vow No Repeat to Gas Shortages, but Warn Exports and Excess Use Must Stop.” Eurasianet, February 24, 2023. https://eurasianet.org/kazakhstan-officials-vow-no-repeat-to-gas-shortages-but-warn-exports-and-excess-use-must-stop.

European Commission. 2022a. “Launch of the Interconnector Greece-Bulgaria.” European Commission, October 1, 2022. https://commission.europa.eu/news/launch-interconnector-greece-bulgaria-2022-10-01-0_en.

European Commission. 2022b. “REPowerEU.” https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/european-green-deal/repowereu-affordable-secure-and-sustainable-energy-europe_en.

European Commission. 2022c. “REPowerEU: A Plan to Rapidly Reduce Dependence on Russian Fossil Fuels and Fast Forward the Green Transition.” European Commission, May 18, 2022. https://neighbourhood-enlargement.ec.europa.eu/news/repowereu-plan-rapidly-reduce-dependence-russian-fossil-fuels-and-fast-forward-green-transition-2022-05-18_en.

European Commission. 2022d. Quarterly report On European gas markets https://energy.ec.europa.eu/document/download/d99eef32-84db-4eb0-99b9-a61cc0cd1419_en?filename=Quarterly%20report%20on%20European%20gas%20markets_Q4%202021.pdf

European Commission. 2023. "Weekly Oil Bulletin 2023." https://energy.ec.europa.eu/data-and-analysis/weekly-oil-bulletin_en.

Gazeta.uz. 2020. "2025 йилга бориб, табиий газни экспорт қилишни тўхтатиш чоралари кўрилади — Абдулла Арипов." Gazeta.uz., January 18, 2020. https://www.gazeta.uz/uz/2020/01/18/gaz-aa/.

IEA (International Energy Agency). 2016. Energy Policies Beyond IEA Countries: Eastern Europe, Caucasus and Central Asia 2015, IEA, Paris https://www.iea.org/reports/energy-policies-beyond-iea-countries-eastern-europe-caucasus-and-central-asia-2015

IEA. 2019. "World Energy Balances (database)." Paris, IEA. https://www.iea.org/data-and-statistics/data-product/world-energy-balances.

IEA. 2020. "World Energy Balances (database)." Paris, IEA. https://www.iea.org/data-and-statistics/data-product/world-energy-balances.

IEA. 2021. *Ammonia Technology Roadmap*. Paris: IEA. https://www.iea.org/reports/ammonia-technology-roadmap.

IEA. 2022a. *Gas Market Report, Q1-2023 (Including Gas Market Highlights 2022)*. Paris: IEA. https://iea.blob.core.windows.net/assets/c6ca64dc-240d-4a7c-b327-e1799201b98f/GasMarketReportQ12023.pdf.

IEA. 2022b. "Fossil Fuel Subsidies Database." IEA, Paris. https://www.iea.org/data-and-statistics/data-product/fossil-fuel-subsidies-database.

IEA. 2022c. *World Energy Outlook 2022*. Paris: IEA. https://www.iea.org/reports/world-energy-outlook-2022.

IEA. 2022d. *Climate Resilience for Energy Security*. Paris: IEA. https://www.iea.org/reports/climate-resilience-for-energy-security.

IEA. 2022e. *World Energy Employment*. Paris: IEA. https://www.iea.org/reports/world-energy-employment.

IEA. 2022f. "World Energy Balances (database)." Paris, IEA. https://www.iea.org/data-and-statistics/data-product/world-energy-balances.

IEA. 2022g. IEA key statements and communications on the natural gas crisis in Europe. Paris, IEA. https://www.iea.org/news/iea-key-statements-and-communications-on-the-natural-gas-crisis-in-europe

IEA. 2023a. *Electricity Grids and Secure Energy Transitions: Enhancing the Foundations of Resilient, Sustainable, and Affordable Power Systems*. Paris: IEA. https://iea.blob.core.windows.net/assets/ea2ff609-8180-4312-8de9-494bcf21696d/ElectricityGridsandSecureEnergyTransitions.pdf.

IEA. 2023b. "ETP Clean Energy Technology Guide." Interactive database. https://www.iea.org/data-and-statistics/data-tools/etp-clean-energy-technology-guide.

IEA. 2023c. "Bioenergy." https://www.iea.org/energy-system/renewables/bioenergy.

IEA. 2023d. "World Natural Gas Information (2023)." https://www.iea.org/data-and-statistics/data-product/natural-gas-information.

IEA. 2023e. "Fossil Fuel Subsidies Database." https://www.iea.org/data-and-statistics/data-product/fossil-fuel-subsidies-database.

IEA. 2024. *Renewables 2023*. Paris: IEA. https://www.iea.org/reports/renewables-2023.

IMF (International Monetary Fund). 2022. "Climate Change: Fossil Fuel Subsidies." IMF, Washington, DC. https://www.imf.org/en/Topics/climate-change/energy-subsidies.

IMF. 2023. "IMF Fossil Fuel Subsidies by Country and Fuel Database (2023)."

IRENA (International Renewable Energy Agency). 2022a. Innovation Outlook: Renewable Ammonia. Abu Dhabi: IRENA. https://www.irena.org/publications/2022/May/Innovation-Outlook-Renewable-Ammonia.

IRENA. 2022b. *Renewable Energy and Jobs: Annual Review 2022*. Abu Dhabi: IRENA. https://www.irena.org/publications/2022/Sep/Renewable-Energy-and-Jobs-Annual-Review-2022.

Jodi Gas. 2023. "The JODI Gas World Database." https://www.jodidata.org/gas/.

Kanudia, Amit. 2023. "KINESYS+ Model Documentation." https://www.kanors-emr.org/models.

Losz, Akos, and Tatiana Mitrova. 2023. "Central Asia's Overlooked Energy Crisis: What It Means for the Global Gas Market." Center on Global Energy Policy at Columbia University, March 28, 2023. https://www.energypolicy.columbia.edu/central-asias-overlooked-energy-crisis-what-it-means-for-the-global-gas-market.

Loulou, R., G. Goldstein, A. Kanudia, A. Lettila, and U. Remme. 2016. "Documentation for the TIMES Model, Part I." Energy Technology Systems Analysis Programme. https://iea-etsap.org/docs/Documentation_for_the_TIMES_Model-Part-I_July-2016.pdf.

Mees. 2023. "Turkey Gas Imports: Russia Still Dominant." Mees, March 3, 2023. https://www.mees.com/2023/3/3/power-water/turkey-gas-imports-russia-still-dominant/f05d2dd0-b9c5-11ed-b549-01302ad8e3d6.

NREL (National Renewable Energy Laboratory). 2023. "Simple Levelized Cost of Energy (LCOE) Calculator Documentation." https://www.nrel.gov/analysis/tech-lcoe-documentation.html.

OECD (Organisation of Economic Co-operation and Development) and FAO (Food and Agricultural Organization). 2022. "Demand for Key Commodities, Food Availability and Agricultural Trade Balance in Europe and Central Asia." In *OECD-FAO Agricultural Outlook 2022–2031*. Paris: OECD Publishing. https://doi.org/10.1787/d1b279e8-en.

Offshore Technology. 2023. "Turkey's TPAO Begins Gas Production from Sakarya Field in Black Sea." Offshore Technology, April 21, 2023. https://www.offshore-technology.com/news/tpao-production-sakarya/?cf-view.

Remme, Uwe, Gary A. Goldstein, Ulrich Schellmann, and Christoph Schlenzig. 2001. "MESAP/TIMES—Advanced Decision Support for Energy and Environmental Planning." In Operations Research Proceedings 2001. https://link.springer.com/chapter/10.1007/978-3-642-50282-8_8.

Reuters. 2023a. "Russia Starts Gas Supplies to Uzbekistan via Kazakhstan." Reuters, October 7, 2023. https://www.reuters.com/markets/commodities/russia-starts-gas-supplies-uzbekistan-via-kazakhstan-2023-10-07.

Reuters. 2023b. "Kazakhstan, China Sign New Gas Supply Contract." October 18. https://www.reuters.com/business/energy/kazakhstan-china-sign-new-gas-supply-contract-2023-10-17

Rystad. 2023a. "Rystad Energy's Upstream Solution, July 2023." https://www.rystadenergy.com/news/underinvestment-global-oil-gas-industry-overblown-efficiency-prices.

Rystad. 2023b. “Oil and Gas Database.” https://www.rystadenergy.com/.

UNFCCC (United Nations Framework Convention on Climate Change). 2015. “Adoption of the Paris Agreement.” Report No. FCCC/CP/2015/L.9/Rev.1. http://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf.

World Bank. 2022a. “Energy Crisis: Protecting Economies and Enhancing Energy Security in Europe and Central Asia.” Policy note, World Bank, Washington, DC. http://hdl.handle.net/10986/38101.

World Bank. 2022b. *Türkiye Country Climate and Development Report*. Washington, DC: World Bank.

World Bank. 2022c. *Kazakhstan Country Climate and Development Report*. Washington, DC: World Bank.

World Bank. 2023a. *The Development, Climate, and Nature Crisis: Solutions to End Poverty on a Livable Planet—Insights from World Bank Country Climate and Development Reports Covering 42 Economies*. Washington, DC: World Bank. http://hdl.handle.net/10986/40652.

World Bank. 2023b. *Uzbekistan Country Climate and Development Report*. Washington, DC: World Bank.

World Bank. 2023c. *Toward a Framework for the Sustainable Heating Transition in Europe and Central Asia.* Washington, DC: World Bank. https://www.worldbank.org/en/region/eca/publication/toward-a-framework-for-the-sustainable-heating-transition.

World Bank. Forthcoming. *The Total Carbon Price: Estimating the Aggregate Pricing Signal from Energy Subsidies, Taxation and Carbon Prices*. Washington, DC: World Bank.

World Bank. Forthcoming. *World Development Report 2024—ECA Companion*. Washington, DC: World Bank.

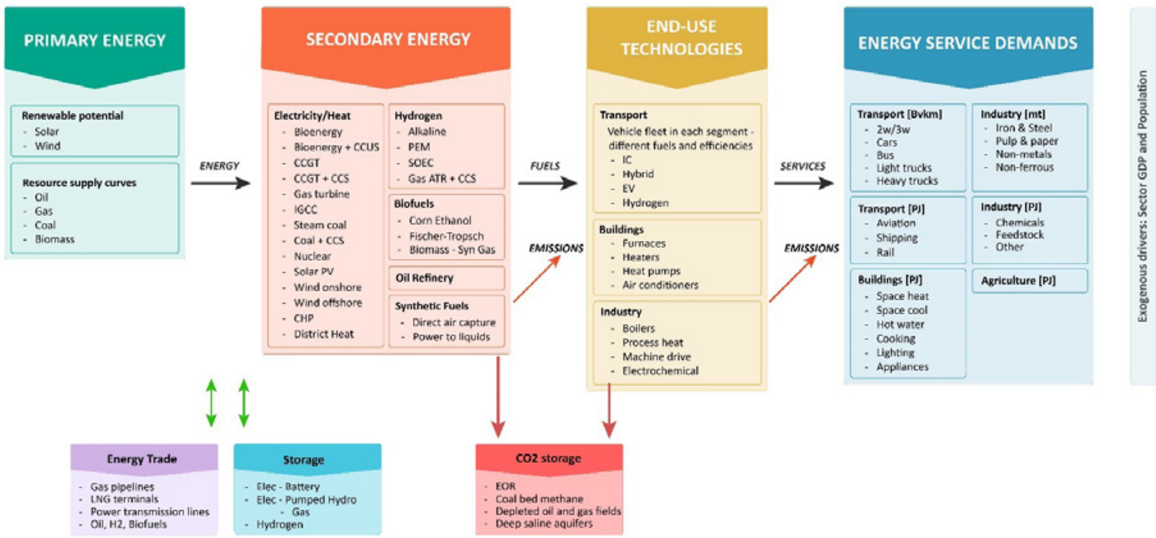
World Bank and ESMAP. Forthcoming. *Barriers to Scale-up of Renewables in Europe and Central Asia*. Washington, DC: World Bank.

World Energy. 2022. “Turkey to Produce Domestic Wind Turbines.” World Energy, January 18, 2022. https://www.world-energy.org/article/22385.html.

APPENDIX 1 • METHODOLOGY OF THE WORLD BANK'S ENERGY MODEL

The World Bank ECA energy model is a multiregional integrated assessment model covering the global energy system. It provides a detailed representation of fuel extraction and transformation, power and heat generation, and three energy end-use sectors (transport, buildings, and industry) (figure A1.1). The model was developed in KINESYS (Knowledge-based Investigation of Energy System Scenarios), a bottom-up, technology-rich, least-cost optimization model developed using IEA-ETSAP's TIMES model generator (Loulou et al. 2016).[27]

Figure A1.1 • Structure of the KINESYS model



Source: Kanudia 2023.

The 2060 modeling horizon is divided into five-year time steps, with 12 time slices per modeling year to represent daily and seasonal variations. ECA is divided into eight subregions (Central Asia, the Caucasus, Europe–East, Europe–Northeast, Russia, Türkiye, Ukraine, and the Western Balkans).

KINESYS simultaneously makes decisions on investments and the operation of assets along the entire energy value chain, including energy supply and trade. In contrast to most top-down modeling approaches, the KINESYS optimization approach does not rely on exogenously given elasticity of substitution parameters to represent technology choice; instead, it leverages a rich representation of supply and demand technologies, for which endogenous fuel cost, operating expense, and exogenous capital cost-related learning curves drive technology-switching to lower-cost alternatives.

KINESYS provides a rich representation of existing and future demand and supply technologies, including investment and operational costs, efficiencies, and learning rates, to account for reductions in technology cost over time. All technologies included in the model are either commercially available today or at a relatively advanced stage of development (past the demonstration and prototype phase, according to the IEA Clean Energy Technology Guide [IEA 2023b]). KINESYS incorporates estimates of the existing stocks of energy-related equipment in all sectors (such as the number of vehicles in transport, production capacity in industry, and floor space area in buildings). It includes a wide variety of traded commodities and a detailed representation of the power and heat sectors down to the generation unit level. Energy service demands, such as steel demand in industry or demand for road travel by car, are important inputs to the model. They

27 KanORS EMR (https://www.kanors-emr.org/models) is one of the developers of KINESYS.

are estimated based on historical data and exogenous socioeconomic drivers. The main socioeconomic drivers for estimating demand are economic growth, provided by the World Bank's global macroeconomics team, and UN population growth projections. A social discount rate of 7 percent is assumed.

KINESYS is calibrated to 2019 energy balances, because disruptions to the global energy system during the COVID-19 pandemic in 2020 and 2021 and the subsequent energy crisis made later data points unreliable as a basis for long term decarbonization analysis. To assess the short- and medium-term impacts of recent upheavals on energy markets and energy security, sensitivities were calculated (such as a stress test reflecting the discontinuation of Russian gas flows to Europe). Historical energy supply, transformation, and demand are based on IEA energy and economic databases; additional data from a wide range of sector-specific external sources inform and improve the data set where possible (table A1.1). During model development, the modeling team made significant extensions to the original model to incorporate ECA–specific characteristics and reflect World Bank experts' view on key input parameters, cross-border infrastructure development plans, climate and energy targets, and policies.

Table A1.1 • Data sources for and inputs into the model

Item	Source	Model input
Base-year characterization	IEA Country Energy Balances (2019)	Base-year fuel production, transformation, and sectoral consumption
Oil and gas supply	Rystad database	Country-level oil and gas supply curves
Oil prices	IEA and historical data-based World Bank projections	Exogenous price curves for selected countries for three scenarios
Gas supply and trade	Global Energy Monitor, World Bank ECA and energy team additions of planned capacities in ECA	Gas pipelines and LNG liquefaction/regasification terminals by country
Gas supply and trade	GIIGNL	LNG liquefaction and trade contracts by country
Renewable energy supply	REZoning (ESMAP n.d.)	Solar, wind onshore, and wind offshore
	EIA	Country-level hydro potential
	EU PV GIS	Solar and wind profiles
	IIASA GLOBIOM model	Country-level biomass potential
Biomass supply and trade	World Bank, IEA, IRENA	Global biomass availability cap of 125 EJ in 2060 as midpoint, based on IEA (100 EJ in 2050 in the Net Zero 2050 scenario[a]) and IRENA analysis (150 EJ biomass availability in 2050[b])
Power sector	SPG Power Plant Database (formerly PLATTs database)	Unit-level power plant capacity (and new additions) by type and vintage
	IRENA	Existing country-level renewable energy capacity and generation
	World Energy Outlook 2022	New power plant technology database
Power trade	ENTSO-E World Bank Energy and Extractives	Europe trade corridors Power and gas cross-border links, with planned future capacities
Demand devices and hydrogen	E3 Modeling	Transportation vehicles and hydrogen technology libraries
	US EPA TIMES model	Building and industry future technology libraries
	EU PV GIS	Country-level HDD/CDD for device capacity factors and heat/cool load shapes
Demand drivers	World Bank GDP projections for every ECA country IPCC SSP scenarios for every other country UN population growth projections	Projections for population and GDP to drive end-use demands
Demand – building renovations	Basic and advances insulation measures	Adopted technology options and costs from *Toward a Framework for the Sustainable Heating Transition in Europe and Central Asia*[c]
New technologies added	Expert inputs from World Bank, IEA, and IRENA	Creation and updating of blue hydrogen and biofuel production equations
Hydrogen production	World Bank ESMAP	Global low-carbon hydrogen production targets added for Net Zero 2060 scenario: United States: 10 Mt; European Union: 10 Mt production and 10 Mt imports by 2030; global: 40 Mt by 2030
Cross-border transmission capacities for hydro and nuclear expansion, electricity, and gas	World Bank ECA country experts	New hydro and nuclear expansion plans and gas and electricity cross-border transmission lines for the 21 ECA countries were collected from country specialists, taking into account planned capacities, units, and commissioning years. Detailed plans for the expansion of gas and electricity transmission were not developed under the scope of this project. The transmission investments estimated here are limited to new cross-border lines and connection of new power generation capacities to existing transmission networks. Additional transmission investments will be needed to scale up the region's electricity systems.

a. IEA (2023c).
b. IRENA (2022).
c. World Bank (2023c).

The model provides a detailed representation of CO_2 emissions. It is particularly well suited to the analysis of energy and environmental policies, which can be represented with accuracy thanks to the explicitness of the representation of technologies and fuels in all sectors. Regional carbon budgets are imposed in the decarbonization scenarios based on discussions with the World Bank's Climate Change Unit. Within subregions, the model can allocate the carbon budget across sectors, unless specified otherwise.

Model outputs include the following:

- Greenhouse gas (GHG) emissions trajectories, including net zero years (per sector, fuel)
- Final energy consumption and primary energy supply (per commodity, sector)
- Technology mix and evolution over time (installed capacity per technology and sector, as well as technology utilization over time)
- Investment costs (over time, per technology and sector)
- Energy supply costs (marginal prices per fuel and sector)[28]
- Marginal emission abatement costs for GHG emissions
- Discounted system costs (per country/region).

Long-term projections and decarbonization analyses are subject to a high degree of uncertainty. The report therefore provides results of sensitivity analyses to assess the implications to changes in some of the most critical assumptions, including economic growth projections and the availability and costs of important decarbonization levers such as bioenergy; carbon capture, usage, and storage (CCUS); and hydrogen and carbon removal technologies. The areas subjected to sensitivity analysis were selected because the assumptions made about them involve a high degree of uncertainty and because they are critical to achieving net zero emissions in the ECA region by 2060.

For comparability reasons, the model uses the same GDP assumption in both main scenarios presented. The sensitivity test with lower GDP projections (equivalent to SSP2) results in significantly lower energy demand and thus smaller investment needs. The higher GDP projection is seen as conservative choice; it shows a higher cost of the energy transition required to sustain greater economic development in ECA. The investment needs presented represent a high growth with high investments narrative in ECA, with high regional connectivity and trade.

Cost sensitivities are built into the scenario design and definitions to represent a wide range of options. They are expressed by different technology capital expense curves reflecting different technology adoption and learning rates in the main scenarios. For example, the cost of solar in the reference case in 2050 is higher than in the Net Zero 2060 scenario because of lower adoption rates and smaller scale. For renewables, the modeling used the cost curves of the International Energy Agency's Stated Policies and Net Zero 2050 scenarios (IEA 2022c).

Sensitivity tests ruling out entire technologies (carbon capture and storage, carbon removal technologies such as direct air capture, green hydrogen, biofuels) suggest that a Net Zero 2060 energy system in ECA is not feasible without carbon removal technologies. In the absence of such technologies, growth of the power sector must be extremely ambitious (historically unseen) or the reliance on unsustainable levels of bioenergy (biomass and biofuels) must be unsustainably higher.

28 Prices, including fuel, end-user, and CO_2 prices, may be inputs to or outputs of the model.

In a sensitivity test without the application of the biomass availability cap, the energy system model results in the withdrawal of unsustainable amounts of biomass. The global availability of biomass in the model was therefore limited to 125 exajoules in 2060.

In a sensitivity where long-distance heavy trucks go electric, hydrogen accounts for 10 percent of final consumption in ECA (compared to 13 percent when the share of electric trucks is not as high).

For the job calculations presented in part 2, the World Bank's energy model outputs were combined with capacity- and investment-based employment factors from the literature to estimate potential direct jobs created by the expansion of renewable energy and heat pumps in ECA. This regional analysis is restricted to estimation of the direct jobs related to these new technologies, because indirect or induced jobs are likely to vary much more by country context. For example, the multipliers that estimate indirect jobs related to the coal industry vary from 0.33 to 0.76 in Poland (Christiaensen et al. 2022) and reach as high as 1.18 in Greece (Christiaensen and Ferré 2020).

The calculation of the levelized cost of ammonia production presented in appendix 3 follows the methodology outlined in NREL 2023.

APPENDIX 2 • DECARBONIZING DISTRICT HEATING

District heating (DH) serves 30 percent of the ECA population, and heating represents 30 percent of buildings' sector total final energy consumption (TFC) in 2060 in the Net Zero 2060 scenario. DH is thus an important technology for decarbonizing heating (and cooling) in the region.

DH serves over 60 percent of the population in Russia and Belarus. If Russia is excluded, it serves around 15 percent of the remaining population of ECA, via approximately 2,300 utilities. Most of the heat generated by DH systems in ECA is used for residential buildings in urban areas. Most of the rest is used in commercial buildings, with a small portion of energy used in power generation through combined heat and power facilities.

Emissions from DH systems are difficult to abate. Around 97 percent of DH systems in the ECA region rely on fossil fuels, with 66 percent relying on natural gas and 29 percent on coal. Coal is often burned in very old plants that are highly inefficient and polluting.

Biomass is one way to decarbonize district heating. Biomass accounts for no more than 30 percent of the fuel used by DH systems in Belarus, Bosnia-Herzegovina, Bulgaria, Croatia, and Poland; in all remaining ECA countries, at least 95 percent of the fuel used in DH systems is fossil fuel. Bioenergy with CCS (BECCS) is considered difficult to implement in DH settings, because the average size is too small to make BECCS financially viable. There is a growing consensus that hydrogen is not the most efficient, economical, or sustainable option for DH systems, because of its inefficiency and low cost-competitiveness for heating.

DH systems in ECA require significant investment to ensure their long-term viability and contribution to decarbonization. Most of the region's systems were built in the Soviet era; lack of maintenance, aging infrastructure, and poor financial viability have left many in poor condition. In some countries, infrastructure collapsed or piping and wiring in DH–connected buildings was removed. And despite DH subsidies, many consumers struggle to pay for the generally higher cost of connecting to a DH system and seek alternative heating options, such as gas boilers. Many systems are also open systems, in which heat is transferred directly, without a heat exchanger, leading to inefficient use of energy and accelerated deterioration of heat transport and distribution networks.

Ownership and governance present additional challenges. Many DH systems are owned and operated, often through bundled heat generation and distribution, by municipal authorities or state-owned enterprises that face significant challenges in terms of financial viability, competitiveness, and governance. There is also wide variation in utility performance across the region and within countries, with only three utilities meeting regional benchmarks. Subsidies and tariffs, which are used to address the lack of cost recovery in many DH installations, undermine the business case for investments in refurbishments and repairs.

Possible measures to reform the DH sector include unbundling generation and distribution and issuing standard heat supply contracts to private produces. Supported by universal consumption-based metering and billing, the latter would allow private developers to enter the DH market, potentially mobilizing investments in networks.

The role of DH in heating and cooling strategies in ECA and the extent to which DH can contribute to decarbonization depend on countries' sustainable heating plans, which must balance the pros and cons of competing technology options in the heating sector. Given robust current and projected global growth in heat pumps, policy makers and investors need to consider carefully the most appropriate options to decarbonize heating.

For buildings that are already connected to a heating network and areas with high heat-demand densities, DH often represents the lowest-cost solution, in both financial and economic terms. Such systems can be retrofitted for electrification, through grid connection and the large-scale deployment of heat pumps. In such settings, energy efficiency improvements, such as piping insulation, metering, and innovations in low-temperature DH systems, can be highly effective in reducing heat losses and improving system viability. In other settings, DH systems may need to be decommissioned, particularly if air source heat pumps can be deployed at scale across single-family and multifamily homes and apartments and commercial and public buildings.

Countries within and outside ECA are exploring ways to ensure the longevity and decarbonization potential of DH systems through targeted incentives and investments and innovations in DH systems and heat networks. Denmark has deployed incentives for large heat pumps, driving significant market growth. Germany has set a target to connect 100,000 homes to DH systems as part of an expansion of heat networks. Some DH networks are also experimenting with low-temperature systems, building-level substations, adding domestic hot water and/or district cooling and heat storage, and more integrated energy sectors that couple electricity with heating.

Given the magnitude of gas heating in ECA, natural gas will likely continue to play a role in the transition of district heating systems in the near term, while electrification and other sustainable fuels gain prevalence in the medium term. Alternatives to new coal and gas-based district heating installations exist in some countries with ample industrial waste heat, hydro and solar resources, geothermal potential, biomass, or sufficient supplies of electricity (e.g., Belarus, Bulgaria, Kyrgyz Republic, Tajikistan, and Türkiye). In parts of Central Asia where few of these options exist (e.g. Uzbekistan) and reliance on coal is heavy (e.g., Kazakhstan), natural gas may represent a viable fuel in the short term for urban consumers already connected to district heating networks.

APPENDIX 3 • LOW-CARBON FERTILIZER PRODUCTION IN CENTRAL ASIA

The effects on Ukrainian grain exports of Russia's intervention in the country highlight the importance of alternative fertilizer production options for a more secure global food value chain. Several ECA countries have a comparative advantage in this market.

Two percent of global total final energy consumption, and 1.3 percent of CO_2 emissions can be attributed to ammonia production. Seventy percent of ammonia is used for fertilizer production (IEA 2021). Ammonia is the main chemical used to produce nitrogen fertilizers, the most widely used fertilizers. Ammonia production is typically based on the energy- and carbon-intensive synthesis of hydrogen and nitrogen that relies mainly on natural gas and, to a lesser extent, coal as fuel or feedstock.

Ammonia produced using only renewable energy sources as fuel and feedstock is known as green ammonia. Ammonia produced using natural gas with carbon capture and storage (CCS) to capture emissions is referred to as blue ammonia. Ammonia produced using the traditional reliance on natural gas without carbon capture and storage (CCS) is referred to as gray ammonia.

The volatility in nitrogen prices has spurred global interest in green ammonia technologies. The constrained supply of fertilizers in the global market, coupled with price volatility and energy transition targets, has prompted efforts to achieve self-sufficiency in fertilizer production. The International Renewable Energy Agency (IRENA 2022a) forecasts that ammonia produced from renewable energy will surpass all other new capacities after 2025, with a projected pipeline of potential projects by 2040 reaching 71Mt.

Ammonia is an important export product for several countries in ECA. It is of critical importance to the prosperity of Central Asia. The subregion's total ammonia production capacity now exceeds 3 million tonnes a year, which requires an estimated 3.5 billion cubic meters of natural gas feedstock a year. Uzbekistan is the largest ammonia producer in Central Asia, accounting for nearly 60 percent of ammonia production, followed by Turkmenistan (32 percent) and Kazakhstan (15 percent).

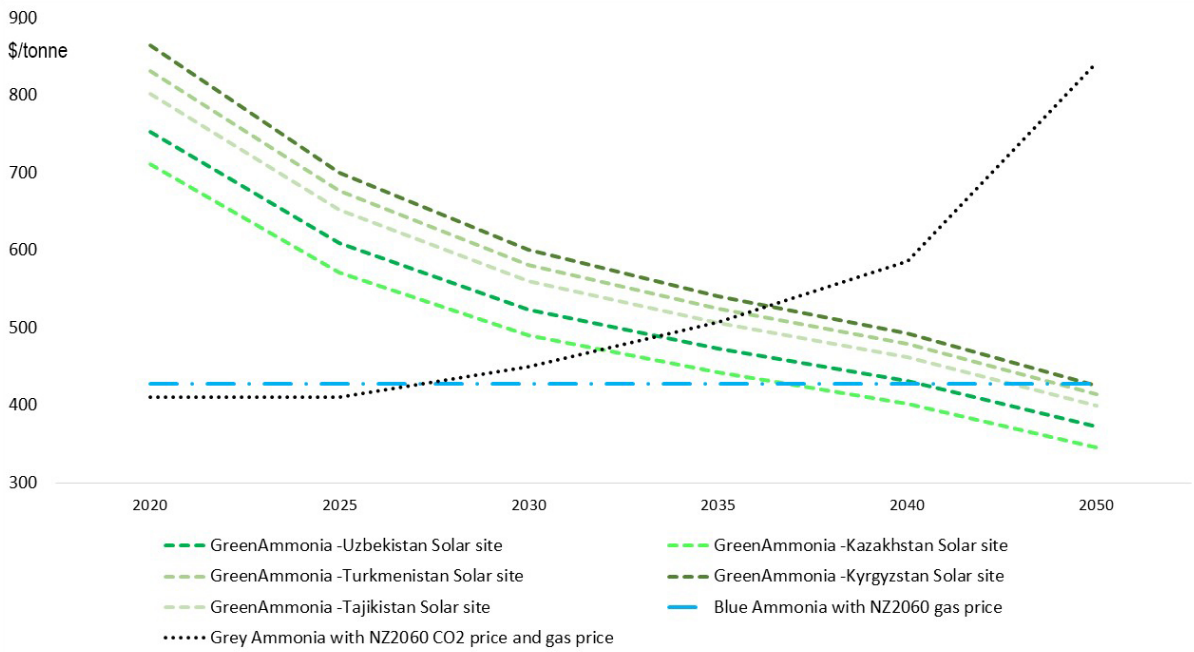
Most ammonia capacities in the Central Asia are outdated. Approximately 30 percent of its ammonia production facilities are at least 40 years old (facilities in Uzbekistan are particularly old). These facilities need gradual replacement within the next 10–15 years. Without investments in new production facilities, Central Asia's production potential can plummet.

Because of their traditional reliance on natural gas as a feedstock, ammonia-based nitrogen fertilizer prices are closely linked to natural gas prices. In early 2021, because of significant natural gas market volatility, prices for nitrogen fertilizers increased by a factor of nearly six. Although the price per tonne of urea (a common nitrogen-based product used as a fertilizer and animal feedstock) has since decreased to less than double 2021 levels, the price shock highlighted important issues for Central Asia. Significant price volatility in feedstock prices not only affects the competitiveness of fertilizer exports; it may also affect the ability to meet domestic demand, with knock-on effects on the region's food security and the competitiveness of its agricultural sector.

Green ammonia offers important potential in Central Asia, not only as a means to decarbonize but also as a way to improve the long-term competitiveness of the region's fertilizer industry while enhancing the security of domestic fertilizer supplies. Central Asian countries have shown increased interest in both green and blue ammonia projects. Preliminary studies for green ammonia production, leveraging hydrogen from water electrolysis and nitrogen from air separation using 100 percent renewable energy, have been announced in Kazakhstan, in collaboration with Svevind from Sweden, and in Uzbekistan, with ACWA Power from Saudi Arabia. Turkmenistan is engaged in discussions with the Korean company Daewoo E&C to construct a large-scale blue ammonia production facility, incorporating CCS technology.

In the Net Zero 2060 scenario, green ammonia production from solar power becomes cost-competitive with gray ammonia between 2030 and 2035, first in Kazakhstan then in Uzbekistan; from 2035, it also becomes cost competitive with blue ammonia. Figure A3.1 compares the levelized cost of energy for producing green ammonia at selected production sites in Kazakhstan, the Kyrgyz Republic, Tajikistan, Turkmenistan, and Uzbekistan, using the variable CO_2 price in line with the Net Zero 2060 pathway for Central Asia for gray ammonia as well as the average Net Zero by 2060 gas price for blue ammonia production. The levelized cost for green ammonia drops from \$700–\$900 in the early 2020s to \$490–\$525 per tonne in 2030, (in Kazakhstan and Uzbekistan, respectively), with green ammonia becoming competitive with gray ammonia in all Central Asian countries between 2035 and 2040. Green ammonia production from wind is projected to be significantly less competitive owing to high capital costs, among other factors.

Figure A3.1 • Levelized cost of green (solar-powered), blue, and gray ammonia production in Central Asia under the Net Zero 2060 scenario



Higher carbon and natural gas prices improve the competitiveness of green ammonia production in Central Asia, but policy makers and investors face significant challenges in terms of scaling this technology in the region. Except for Turkmenistan, all Central Asian countries also face challenges in meeting domestic natural gas demand, which affects the availability of gas feedstock in the short to medium term during an eventual ramp-up of green ammonia production. This issue is particularly relevant given strong historical and projected population growth rates. Between 1991 and 2023, the population of Central Asia grew 50 percent, from 51.9 to 78.2 million. By 2050, the population of Central Asia is expected to grow another 33 percent, to exceed 100 million people.

These challenges are compounded by a high fertilizer intensity in Central Asia, where crops such as cotton and wheat require substantial amounts of nitrogen fertilizers. Fertilizer consumption is nearly twice the world average in Uzbekistan and 13 percent above the world average in Turkmenistan. According to the estimates by the Organisation of Economic Co-operation and Development and the Food and Agricultural Organization (OECD and FAO 2022), the agricultural trade deficit in Central Asia will increase from 4.4 percent in 2020 to 6.1 percent in 2031.

Central Asian countries can address these challenges through several policy measures. Elimination of natural gas subsidies would address price distortions and improve the cost-effectiveness of green ammonia. Robust decarbonization strategies and policy frameworks, enhanced by dedicated funding instruments for green ammonia production, would send encouraging signals to investors. Improvements in countries' investment climates and a lower cost of capital would improve the business case for new large-scale investments in green ammonia.

APPENDIX 4 • SELECTED LIQUID FUEL PRICING SUBSIDIES IMPLEMENTED IN EUROPE AND CENTRAL ASIA

Table A4.1 • Selected liquid fuel pricing measures implemented in Europe and Central Asia in 2022, by country

Country	Measure
Bulgaria	Bulgaria introduced a discount of 0.25 levs ($0.12) per liter of gasoline and diesel from July 9 to December 31, 2022. The government also waived the excise tax on automotive LPG through June 30, 2025.
Croatia	Since March 2022, Croatia has set a price cap on 95-octane gasoline and diesel at stations located outside highways; premium fuels can be sold at market prices. The retail market has 961 gas stations, of which just 70 are located on highways.
Czech Republic	In May 2022, the government temporarily reduced excise duties on diesel and gasoline by CZK1.50 per liter, effective June 1–September 30, 2022.
Estonia	In June 2022, the government reduced the value added tax (VAT) for "special purpose diesel fuel" to the minimum rate permitted in the European Union. The reduction sought to alleviate the effect on the agricultural sector and oil shale mines, which experienced considerable increase in input costs from high fuel prices in 2022. In June 2023, the government announced that it would maintain the reduced VAT, mainly to support the competitiveness of Estonian agricultural producers.
Hungary	In November 2021, the government capped retail fuel prices at Ft 480 ($1.21) per liter, substantially below market prices and the lowest price in the European Union. Price caps led to a surge in demand from trucks transiting through Hungary and from retail buyers from neighboring countries. Fuel importers were unable to recoup costs and had to reduce imports. Technical issues in the domestic refinery further constrained domestic supply, resulting in widespread fuel shortages. After 13 months, on December 6, 2022, the government removed all fuel price caps.
Montenegro	In May 2022, the government reduced fuel excise duties by 40 percent.
North Macedonia	In March 2022, the government temporarily reduced VAT on fuels from 18 percent to 10 percent for two months. In June 2022, it decided not to extend the measure, and the VAT was increased back to 18 percent.
Poland	In 2022, the government extended a range of measures it introduced before the war in Ukraine to control inflation. As part of this package, it reduced the VAT on liquid fuels from 23 percent to 8 percent through December 31, 2022.
Serbia	The government has set a weekly price cap on gasoline and diesel since February 2022. In April 2022, it reduced the excise duty on gasoline and diesel by 15 percent.
Slovenia	Slovenia started capping the price of gasoline and diesel in March 2022. In June 2022, the government deregulated the prices of motor fuels sold along motorways but kept price caps on fuel sold at service stations outside motorways.

APPENDIX 5 • GREENHOUSE GAS EMISSIONS IN THE EUROPE AND CENTRAL ASIA REGION IN 2020

ECA countries' 2020 total greenhouse gas (GHG) emissions vary widely (table A5.1). Emissions from Russia—the region's largest emitter—account for 3.79 percent of global GHG emissions. Other significant emitters in the region include Türkiye (1.00 percent), Poland (0.68 percent), Kazakhstan (0.61 percent), Ukraine (0.47 percent), and Turkmenistan (0.41 percent).

Table A5.1 • Global greenhouse emissions and emissions within Europe and Central Asia, by country, 2020

Country	Total emissions ($MtCO_2e$)	Percent of world total	Total emissions per capita (tCO_2e/capita)	Status of Country Climate and Development Report
World	46,120.92	100.0	5.94	
Europe and Central Asia	4,571.03	9.91	11.40	
Albania	8.3	0.02	2.93	In preparation (FY24)
Armenia	10.42	0.02	3.52	In preparation (FY24)
Azerbaijan	55.35	0.12	5.48	Published (FY23)
Belarus	87.87	0.19	9.37	Not yet scheduled
Bosnia and Herzegovina	26.05	0.06	7.94	In preparation (FY24)
Bulgaria	46.49	0.10	6.71	Not yet scheduled
Croatia	21.38	0.05	5.28	Not yet scheduled
Georgia	17.67	0.04	4.75	In preparation (FY25)
Kazakhstan	294.81	0.64	15.72	Published (FY22)
Kosovo	—	—	—	In preparation (FY24)
Kyrgyz Rep.	16.09	0.03	2.45	Scheduled (FY25)
Moldova	12.99	0.03	4.96	In preparation (FY24)
Montenegro	3.76	0.01	6.06	In preparation (FY24)
North Macedonia	9.77	0.02	4.71	In preparation (FY24)
Poland	338.38	0.73	8.93	Scheduled (FY24)
Romania	95.74	0.21	4.97	In preparation (FY23)
Russian Fed.	2,331.48	5.06	16.18	On hold (FY22)
Serbia	62.88	0.14	9.11	In preparation (FY24)
Tajikistan	17.69	0.04	1.85	In preparation (FY24)
Türkiye	504.96	1.09	5.99	Published (FY22)
Turkmenistan	194.09	0.42	32.18	Not yet scheduled
Ukraine	227.34	0.49	5.15	On hold (FY22)
Uzbekistan	187.52	0.41	5.48	Published (FY23)

Source: Climate Watch Historical GHG Emissions, Total GHG excluding LUCF; World Bank Databank Development Indicators.

Note: — Not available.