IRENA
International Renewable Energy Agency

RENEWABLE ENERGY ROADMAP

EASTERN PARTNERSHIP

Funded by the European Union

ISBN: 978-92-9260-677-0

Citation: IRENA (2025), *Renewable Energy Roadmap: Eastern Partnership*, International Renewable Energy Agency, Abu Dhabi.

About IRENA

The International Renewable Energy Agency (IRENA) is an intergovernmental organisation that supports countries in their transition to a sustainable energy future, and serves as the principal platform for international co-operation, a centre of excellence, and a repository of policy, technology, resource and financial knowledge on renewable energy. IRENA promotes the widespread adoption and sustainable use of all forms of renewable energy, including bioenergy, geothermal, hydropower, ocean, solar and wind energy, in the pursuit of sustainable development, energy access, energy security and low-carbon economic growth and prosperity. **www.irena.org**

Acknowledgements

This report was prepared by IRENA in collaboration with the European Commission and benefited from consultations with Member States.

IRENA is grateful for the support, guidance and constructive engagements received from the European Commission and Member States. Special thanks for support and guidance of the project go to Erwann Martin, Darya Mustafayefa, Michal Dlugosz and Klara Orlowska from the Directorate-General for Enlargement and the Eastern Neighbourhood (DG ENEST, previously DG NEAR); and to all the representatives of the Eastern Partnership countries who participated in the engagement workshop in April 2025. IRENA is also grateful for the funding provided by the European Commission for this study.

The report was developed under the guidance of Norela Constantinescu (Acting Director, IRENA Innovation and Technology Centre) and Roland Roesch (former Director, IITC) and was led by Ricardo Gorini. It was authored by Seán Collins, Milenko Matosic Suárez (IRENA); María Vicente García and Adam Adiwinata (consultants).

IRENA also would like to express sincere appreciation to the following technical experts who provided valuable inputs: Varvara Aleksić, Simon Benmarraze, Petya Icheva (IRENA), and Nicholas Wagner, Pablo Rimancus and Daniel Carrillo (formerly of IRENA).

Publication and editorial support were provided by Francis Field and Stephanie Clarke. Technical review was provided by Paul Komor. The report was edited by Steven B. Kennedy, with design provided by Nacho Sanz.

For further information or to provide feedback: **publications@irena.org**

This report is available for download: **www.irena.org/publications**

FOREWORD

Francesco La Camera

Director-General

International Renewable Energy Agency

The global imperative to accelerate the energy transition has never been clearer, nor more urgent. As countries navigate growing geopolitical insecurity, economic pressures and climate change, the focus of policy-makers is increasingly on building resilient economies and energy systems.

Regions around the world are seeking pathways that align climate action with energy security, economic resilience and long-term development. The countries of the Eastern Partnership are no exception. Comprising Armenia, Azerbaijan, Georgia, the Republic of Moldova and Ukraine, the region faces a rapidly evolving geopolitical landscape, heightened energy security risks and increasing exposure to global market volatility. Yet within these challenges lie profound opportunities to strengthen regional cooperation, increase energy security and advance an inclusive energy transition.

This Renewable Energy Roadmap for the Eastern Partnership countries outlines a clear and actionable pathway, offering a strategic assessment of how the region can design and implement its energy transition in a timely manner. It highlights the importance of accelerating renewable energy deployment, modernising energy infrastructure and scaling up investments. Most importantly, it emphasises the crucial role of regional cooperation in the form of shared infrastructure development and knowledge exchange.

The power sector can deliver profound efficiency gains across the energy system by enabling deep and rapid decarbonisation through electrification of energy end-uses. Integration of infrastructure within the Eastern Partnership, and connections both within these countries and with the wider neighbourhood and European Union, can reduce costs and improve security. This study demonstrates that EUR 17 billion per year is needed for power sector investments as part of the EUR 62 billion per year required for the energy transition as a whole. Regional cooperation can enable a sharing of costs, risks and renewable resources that can provide a lower-cost, mutually reliant system for all.

IRENA remains steadfast in its commitment to supporting the energy transition in the Eastern Partnership countries. The transition offers a strategic opportunity to both modernise energy systems and unlock new economic pathways and regional co-operation. I encourage all stakeholders in the Eastern Partnership to embrace this opportunity with clarity and purpose, and to lead by example in advancing the shared objectives of regional stability and global climate action.

CONTENTS

FIGURES

TABLES

ABBREVIATIONS

CCS	carbon capture and storage
CCUS	carbon capture, utilisation and storage
CHP	combined heat and power
CO_2	carbon dioxide
CSP	concentrated solar power
DES	Decarbonising Energy Scenario
DRI	direct-reduced iron
EaP	Eastern Partnership
EJ	exajoule
ENTSO-E	European Network of Transmission System Operators for Electricity
ETS	Emissions Trading System
EU	European Union
EUR	Euro
EV	electric vehicle
FEC	final energy consumption
GDP	gross domestic product
GHG	greenhouse gas
Gt	gigatonne
$GtCO_2$	gigatonne of carbon dioxide
GW	gigawatt
GWh	gigawatt hour
ICAO	International Civil Aviation Organisation
ICE	internal combustion engine
IEA	International Energy Agency
INECP	Integrated National Energy and Climate Plan
IRENA	International Renewable Energy Agency
KPI	key performance indicator
Mt	million tonnes
$MtCO_2$	million tonnes of carbon dioxide
NDC	Nationally Determined Contribution
NECP	National Energy and Climate Plan
PES	Planned Energy Scenario
PJ	petajoule
p-km	passenger kilometre
PV	photovoltaic
R&D	research and development
RE	renewable energy
Remap	Renewable Energy Roadmap
SCADA	supervisory control and data acquisition
T&D	transmission and distribution
t-km	tonne-kilometre
TWh	terawatt hour
USAID	United States Agency for International Development
VRE	variable renewable energy

EXECUTIVE SUMMARY

The Eastern Partnership (EaP) countries analysed in this report – Armenia, Azerbaijan, Georgia, the Republic of Moldova and Ukraine – are striving to establish a secure and affordable energy system as they work towards decarbonising their economies. Ukraine represented 72% of the region's final energy consumption in 2021, followed by Azerbaijan, Georgia, the Republic of Moldova and Armenia. Ukraine and Azerbaijan are expected to remain the leaders in energy demand through 2050 in both of the scenarios considered here.

Two scenarios are developed in this analysis, the Planned Energy Scenario (PES) and the Decarbonising Energy Scenario (DES). The PES, the reference case for the study, is based on current energy plans and strategies. The DES represents an alternative and more ambitious scenario for decarbonisation of the economy.

There is a gap between the PES and DES in the short and long term. Achieving the decarbonisation results proposed in the DES by 2050 will require policy changes to enable a deeper transformation of the energy sector and economy of each EaP country. Clear objectives in the power sector and all end-use sectors will be necessary if a decarbonisation roadmap with clear milestones is to be drawn. Additionally, tools for monitoring, reporting and verification of the objectives in each sector will be needed to track decarbonisation

To decarbonise, actions across all sectors are needed. Renewable generation powering deep electrification is the main decarbonisation pathway in the region, complemented by strong energy efficiency measures as well as the use of bioenergy and hydrogen and its derivatives.

Total primary energy supply under the PES is projected to increase by 18% over 2021 levels by 2050, reaching a renewable energy share of 20%, up from 7% in 2021. Final energy consumption (FEC) by 2050 is expected to remain at around 2021 levels, and to reach a total renewables share of 19% by 2050, up from 9% in 2021. This rise reflects heavier use of renewable energy in end-use sectors, driven by the electrification of the transport fleet, heating services in buildings and low-temperature processes in industry.

The DES presents a more ambitious scenario for decarbonisation of countries' economies. Total primary energy supply in this scenario is projected to be 7% higher in 2050 than in 2021, reaching a renewable energy share of 51%. On the other hand, FEC is expected to drop 22% by 2050 from the 2021 level owing to efficiency gains in this scenario. The total renewable energy share in FEC is expected to reach 47% in 2050. The main decarbonisation pathway in all end-use sectors is the electrification of demand and the implementation of far-reaching energy efficiency measures.

By 2050, energy-sector-related emissions under the DES are expected to be 66% lower than under the PES. The difference is driven by lower energy consumption in the DES (25% lower than in the PES by 2050), and a higher renewable energy share, despite the activity growth in all sectors.

Electrification is projected to account for 25% of final energy consumption by 2050 in the PES and 46% in the DES, compared to 20% today. Electric mobility, electrification of heating applications for buildings and low-temperature industrial processes are expected to play the key roles.

Renewable power generation capacity increases by 40% in the PES and 100% in the DES by 2030, reaching 32 gigawatts (GW) and 46 GW, respectively, in comparison with 23 GW in 2021. By 2050, capacity grows 2.6 times over 2021 levels in the PES and more than six times in the DES. Achieving either of these levels of ambition will require sustained net additions of renewables by 2050 averaging 1.3 GW per year (in the PES) and 4.1 GW per year (in the DES) over 2021 levels, re-shaping regional power systems and enabling more stable, less volatile electricity costs in the long run.

Solar and wind drives most of the new capacity in the DES, with utility-scale solar photovoltaic (PV) reaching 55 GW and wind (both onshore and offshore) expanding to 64 GW by 2050. Average annual net additions of 1.6 GW for solar and 2.1 GW for wind will be required to reach 2050 DES levels from 2021. In this Scenario, Ukraine is expected to lead in both solar PV and wind technologies, with Azerbaijan also playing a key role in offshore wind. Other countries contribute at smaller scales, reflecting varying national potentials and development pathways.

Total investments in power generation, system flexibility and grids between 2025 and 2050 are projected to be approximately EUR 174 billion in the PES and EUR 292 billion in the DES, or EUR 7 billion and EUR 11 billion annually in the PES and DES, respectively. The DES entails significantly higher annual average investment over the 2025-2050 period in onshore wind (EUR 2 billion), solar PV (EUR 1 billion) and offshore wind (EUR 1.4 billion). This is cumulatively more than three times larger than the investment needs in these technologies in the PES, reflecting the scale of the accelerated deployment. Annual investments in transmission and distribution infrastructure will also rise, reaching EUR 1.6 billion in the PES and EUR 2.1 billion in the DES, to support the integration of high shares of variable renewables.

Variable renewable electricity rises to nearly 60% of total generation by 2050 in the DES, necessitating urgent investments to ensure flexibility and resilience. Battery storage must grow from zero in 2021 to 12.6 GW by 2050 in the DES, alongside expanded and strengthened cross-border inter-connections. Without rapid grid modernisation and sector coupling, the system risks increased curtailment and volatility. Dispatchable technologies such as bioenergy, natural gas, and thermal-based hydrogen will play a critical role in balancing seasonal variability. Delivering this transformation will depend not only on infrastructure upgrades but also on a systemic shift in how energy systems are planned, integrated and operated.

A cumulative EUR 1.3 trillion is required in energy transition investments in the PES through 2050, while in the DES, an annual investment of about EUR 62 billion will be needed, for a cumulative investment of EUR 1.6 trillion. Annual investment under the DES is up to 1.2 times what is required under the PES between 2025 and 2050, driven mainly by the greater investment needed to decarbonise end-use sectors, develop renewable capacity, expand the grid, and develop carbon capture and storage. The cumulative investment requirement in the DES is 7.8 times the region's total gross domestic product for 2021. Decarbonisation of the transport sector (including charging infrastructure) and buildings makes up about 62% of the region's total investment needs.

Regional integration and infrastructure planning will be essential to implement the DES. Joint infrastructure projects between neighbouring countries could facilitate cost-sharing, improve system efficiency, and help unlock access to international financing. Strengthening regional co-operation and planning would also support more co-ordinated development of cross-border grids, renewable energy zones, and market integration.

Financing will also play a key role in achieving the efforts proposed under the DES. While cumulative investment needs are high, current financing in the region remains limited and fragmented, with a heavy reliance on external support. National and regional development banks will be vital in designing specific financing mechanisms for the EaP countries to implement the measures proposed in the DES, helping to bridge the gap and attract sustainable investment.

INTRODUCTION

The European Commission asked the International Renewable Energy Agency (IRENA) to develop a Renewable Energy Roadmap for the Eastern Partnership (EaP) countries to explore opportunities for cost-effective transformation of the energy sector through regional co-operation. This analysis examines the energy landscapes of Armenia, Azerbaijan, Georgia, the Republic of Moldova and Ukraine, with a focus on advancing the region's energy transition by 2030 (short term) and 2050 (long term).

IRENA's analysis offers a comprehensive assessment of the EaP's energy sector under two scenarios: the Planned Energy Scenario and the Decarbonising Energy Scenario.

1. **The Planned Energy Scenario (PES)** is the primary reference case for this study. It represents a transition pathway consistent with decarbonisation plans as of March 2025. Current policies, plans, National Energy and Climate Plans, Nationally Determined Contributions and other relevant documents were reviewed. Current targets were included in this scenario.
2. **The Decarbonising Energy Scenario (DES)** presents an alternative pathway for reaching the goal of decarbonising the EaP countries' economies and contributing to achieving the 1.5°C global warming limit of the Paris Agreement.

The analysis includes energy transition pathways, both for energy supply (power generation and fuels, including hydrogen and its derivatives, biofuels) and end-use sectors (buildings, industry and transport), for the period from 2021 to 2050. It also includes a high-level examination of the potential impacts of accelerated deployment of renewables in the EaP power systems of 2050.

The analysis benefited from extensive data collection sourced from government national plans, country strategies, other reference documents, as well as consultations with country experts. Table I.1 details the regulations, plans, strategies and other relevant documents considered in the development of the PES and DES.

The analysis and its results were discussed with Member States and other experts in an online consultation workshop held in April 2025; the workshop was marked by extensive input and feedback. The study and its recommendations have been designed to help policy makers and stakeholders shape the energy transition in the region.

Key questions that policy makers may wish to discuss while formulating new directives and regulations include:

- Is the 2050 1.5°C target technically feasible?
- How close would current plans and policies implemented domestically bring the EaP countries to the 1.5°C target by 2050?
- What is the key focus for policy making in the coming years? What is the best strategy to reduce emissions?
- Which technologies and energy carriers will dominate in the coming decades?
- What are the gaps in policies, regulation and market designs for implementing the targets in different sectors?
- What are the investment costs and subsequent impacts on energy prices for consumers?

The report is structured as follows. Chapter 1 presents overall results of the REmap analysis for the EaP, accompanied by key insights and messages. Chapter 2 presents the main outcomes, findings and messages for the transport sector. Chapter 3 does the same for the industrial sector; Chapter 4 for the buildings sector; and Chapter 5 for the power sector (including hydrogen and its derivatives). Chapter 6 highlights the investment needs for the region's energy transition.

Table I.1 Regulations, plans and strategies considered in developing the two scenarios

COUNTRY	SOURCES CONSULTED	REFERENCE
Armenia	• Armenia Least Cost Development Plan 2024-2050	(USAID, 2022)
	• Long-term (until 2050) Low Emissions Development of the Republic of Armenia	(Government of Armenia, 2023)
	• Strategy Draft for Electric Mobility Development in Armenia	(Government of Armenia, 2024)
	• In-Depth Review of the Energy Efficiency Policy of Armenia	(Energy Charter Secretariat, 2015)
	• Armenia Energy Policy Review	(IEA, 2022a)
	• Accelerating Energy Efficiency Initiatives and Opportunities in Eastern Europe, Caucasus and Central Asia	(Copenhagen Centre on Energy Efficiency, UNEP, 2015)
	• Law on Energy Saving and Renewable Energy	(Government of Armenia, 2004)
	• Energy Sector Development Strategic Program to 2040	(Government of Armenia, 2020)
	• Program on Energy Saving and Renewable Energy for 2022–2030	(Government of Armenia, 2022)

Azerbaijan	• National plan on electromobility: 2025-2030 draft (shared in September 2024)	(Government of Azerbaijan, 2024)
	• The Republic of Azerbaijan Updated Document on Nationally Determined Contributions (NDCs)	(Government of Azerbaijan, 2023)
	• Azerbaijan Energy Policy Review	(IEA, 2021)
	• Country Climate and Development Report	(World Bank, 2023)
	• Azerbaijan National Hydrogen Strategic Outlook	(Republic of Azerbaijan, 2024)
	• Energy Efficiency Policy in Azerbaijan: A Roadmap	(IEA, 2024)
	• Law on the Use of Renewable Energy Resources in Electricity Production (2021)	(Ministry of Energy of Azerbaijan, 2021)
	• Law on the Use of Energy Resources and Energy Efficiency	(Government of Azerbaijan, 2021)
	• Nationally Determined Contribution 2.0 Azerbaijan	(Government of Azerbaijan, 2023)
Georgia	• Integrated National Energy and Climate Plan of Georgia	(Government of Georgia, 2023)
	• National Renewable Energy Action Plan	(Government of Georgia, 2019)
	• Energy Efficiency Retrofitting of Residential Buildings: Solutions and Recommendations	(World Bank, 2020a)
	• Energy Consumption in Households	(National Statistics Office of Georgia, 2022)
	• Accelerating Energy Efficiency Initiatives and Opportunities in Eastern Europe, Caucasus and Central Asia	(Copenhagen Centre on Energy Efficiency, UNEP, 2015)
	• Ten-Year Network Development Plan (2024–2034)	(Georgian State Electrosystem, 2024)
Republic of Moldova	• Integrated National Energy and Climate Plan of Moldova	(Government of the Republic of Moldova, 2023)
	• Accelerating Energy Efficiency Initiatives and Opportunities in Eastern Europe, Caucasus and Central Asia	(Copenhagen Centre on Energy Efficiency, UNEP, 2015)
	• Moldova Annual Implementation Report	(Energy Community, 2024a)
	• Moldova Energy Policy Review	(IEA, 2022b)
	• Energy Strategy of Moldova 2030	(Government of the Republic of Moldova, 2012)
	• Ten-Year Network Development Plan (2018–2027)	(Moldelectrica, 2018)
Ukraine	• Clean Energy Roadmap: from Reconstruction to Decarbonisation in Ukraine	(Ministry of Energy of Ukraine, 2023)
	• National Energy and Climate Plan of Ukraine 2025-2030 draft	(Government of Ukraine, 2024b)

1

THE ENERGY TRANSITION IN THE EASTERN PARTNERSHIP

This chapter describes the overall results of the Renewable Energy Roadmap (REmap) analysis for the Eastern Partnership (EaP) countries and aims to provide clarification for policy makers on the following questions:

1. How will the EaP's energy sector evolve considering the targets defined in current plans, policies and other relevant documents?
2. How will each sector contribute to economy-wide decarbonisation, and where are the existing gaps?
3. Which decarbonisation pathways, measures or actions will have the greatest impact in each of the sectors?

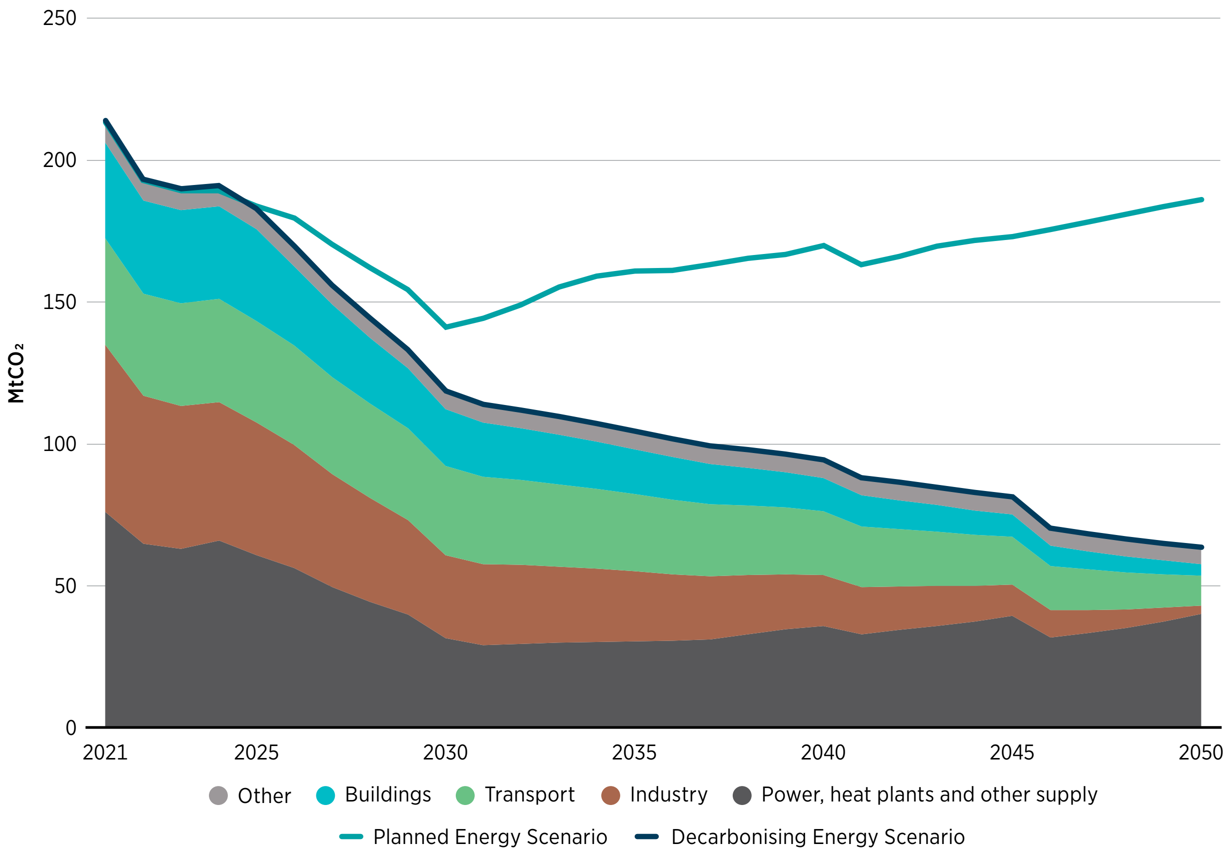
1.1 GLOBAL CHALLENGES AND THE EAP'S POTENTIAL FOR ENERGY TRANSITION

Global annual energy- and process-related carbon dioxide (CO_2) emissions in 2050 may reach 36.5 gigatonnes of carbon dioxide ($GtCO_2$), according to the Planned Energy Scenario (PES) developed in IRENA's 2024 *World Energy Transitions Outlook*. IRENA's 1.5°C Scenario, by contrast, envisions a way to achieve net-zero emissions by 2050, aligning with the Intergovernmental Panel on Climate Change's special report to limit global warming to no more than 1.5°C. In this context, the energy sector plays a central role in the global effort to reduce emissions.

Global energy-related emissions amounted to 36.3 Gt (IEA, 2025) in 2021. EaP countries contributed 0.6% of those emissions, or 0.21 Gt. Although the EaP countries' emissions represent a small share, it is important for all countries, including smaller emitters, to take action. Achieving the goals of the Paris Agreement requires collective action, and the engagement of all countries helps ensure fairness, promotes technological innovation and co-operation, and prevents emissions leakage. Moreover, early action by all countries can help them avoid future economic and social costs associated with climate impacts and transition risks.

As shown in Figure 1.1, EaP's emissions levels in the PES by 2050 are expected to be 13% lower than the 2021 levels. After 2030, emissions are expected to show an increasing trend owing to economic expansion, mitigated somewhat by policies and national targets among the Member States to reduce the impact of the energy sector on climate. In comparison, the Decarbonising Energy Scenario (DES) outlines a pathway for the region to advance its energy transition efforts, aiming to reduce emissions by approximately 70% by 2050 relative to 2021. This represents a difference of 66% compared to the PES in 2050.

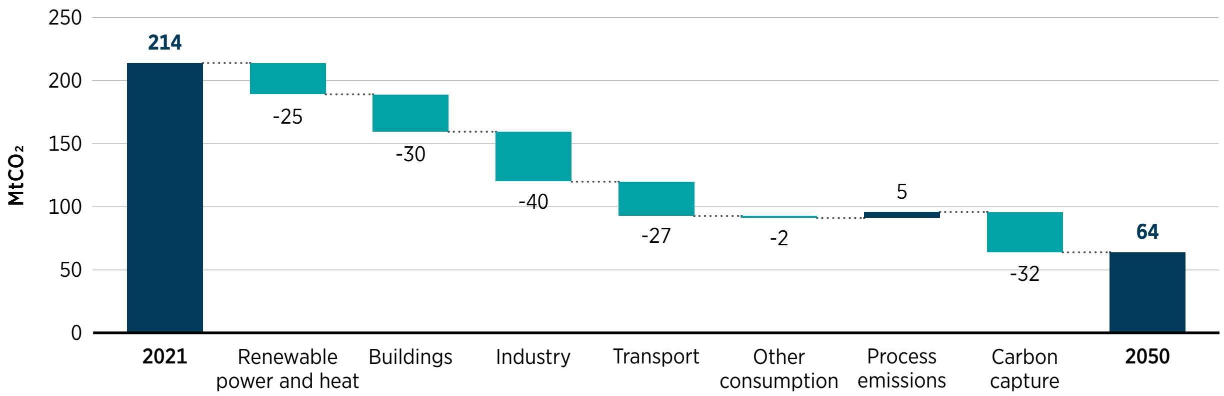
Figure 1.1 EaP's CO_2 emissions in the two scenarios



Note: EaP = Eastern Partnership; $MtCO_2$ = million tonnes of carbon dioxide.

The emissions reduction in the DES is achieved thanks to decarbonisation measures in the various sectors, as the activity considered in both scenarios is the same. The contribution of each sector or method to the decrease is depicted in Figure 1.2. Industry, buildings and transport are the sectors that contribute the most to the emissions reduction by 2050 in the DES compared to the 2021 levels.

Figure 1.2 EaP's CO_2 emissions reduction by 2050 over 2021 in the DES, by sector or method



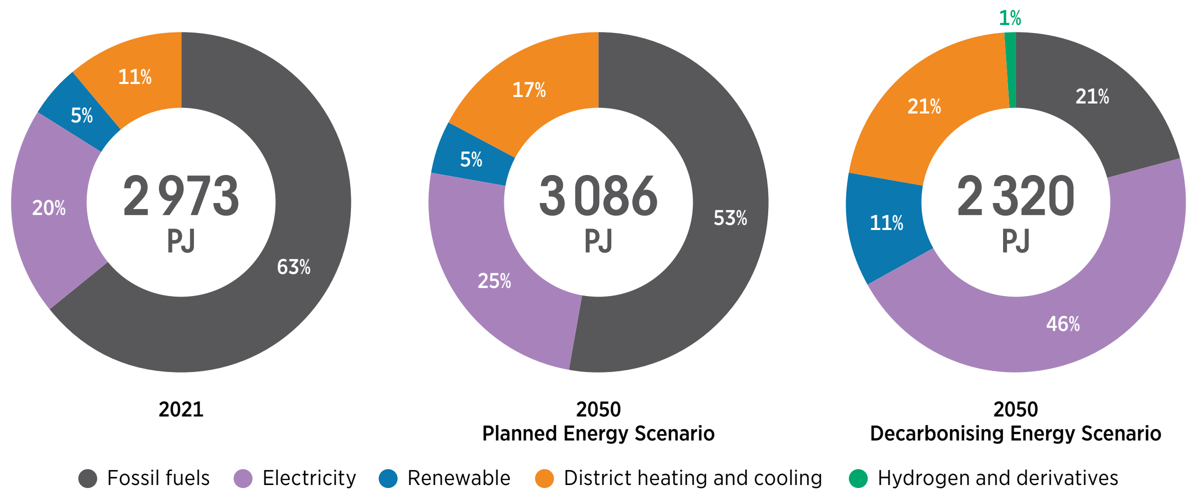
Notes: CO_2 = carbon dioxide; DES = Decarbonising Energy Scenario; EaP = Eastern Partnership; $MtCO_2$ = million tonnes of carbon dioxide.

1.2 FINAL ENERGY CONSUMPTION

The region's emissions trend is linked to its final energy consumption. The upward trend in the PES is moderated by the use of renewables and implementation of energy efficiency measures as described in current plans. Their effect is even more apparent when the region optimises the deployment of all the potential energy transition options available, as described in the DES, reaching 30% less emissions by 2050 compared to 2021.

The DES envisions a transition driven by the deployment of renewable energy, improvements in energy efficiency and deep electrification of end-use sectors. Electricity becomes the main energy carrier by 2050 owing to its cost competitiveness and scalability. The shift would result in electricity accounting for about 46% of energy consumption by 2050 in the DES, a substantial increase from 2021 levels (see Figure 1.3). Alongside direct electrification, bioenergy and other direct renewables such as biofuel (11%) and clean hydrogen and its derivatives (1%) would also play a role in decarbonising hard-to-abate sectors for which alternatives are limited.

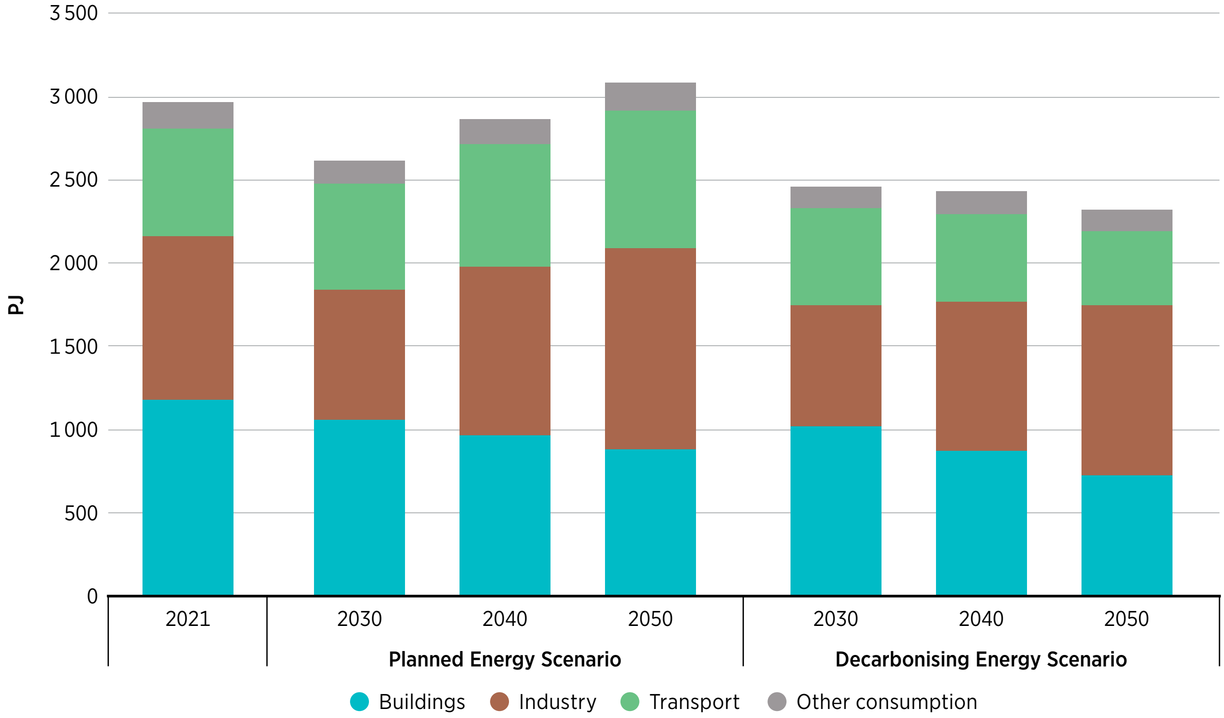
Figure 1.3 Shares of final energy consumption in the two scenarios, by energy type, 2021 and 2050



Note: PJ = petajoule.

Despite ongoing national energy transition efforts, energy consumption in the PES is projected to rise over current levels in absolute terms, driven by continued growth in economic activity and demand for energy services. Energy consumption for industry and transport is projected to be 25% higher than in 2021, reaching 2 041 petajoules (PJ) by 2050 in the PES. Driven by the EaP countries' plans, energy efficiency plays an important role in the PES, keeping annual growth of the two sectors' energy consumption to just 0.8%. The role of energy efficiency becomes more apparent in the buildings sector, reducing the sector's energy consumption by 25% so that it reaches 882 PJ by 2050 (Figure 1.4). Total energy consumption in the DES is 25% lower in 2050 than in the PES, reaching 2 320 PJ.

Figure 1.4 Final energy consumption under the two scenarios, by sector

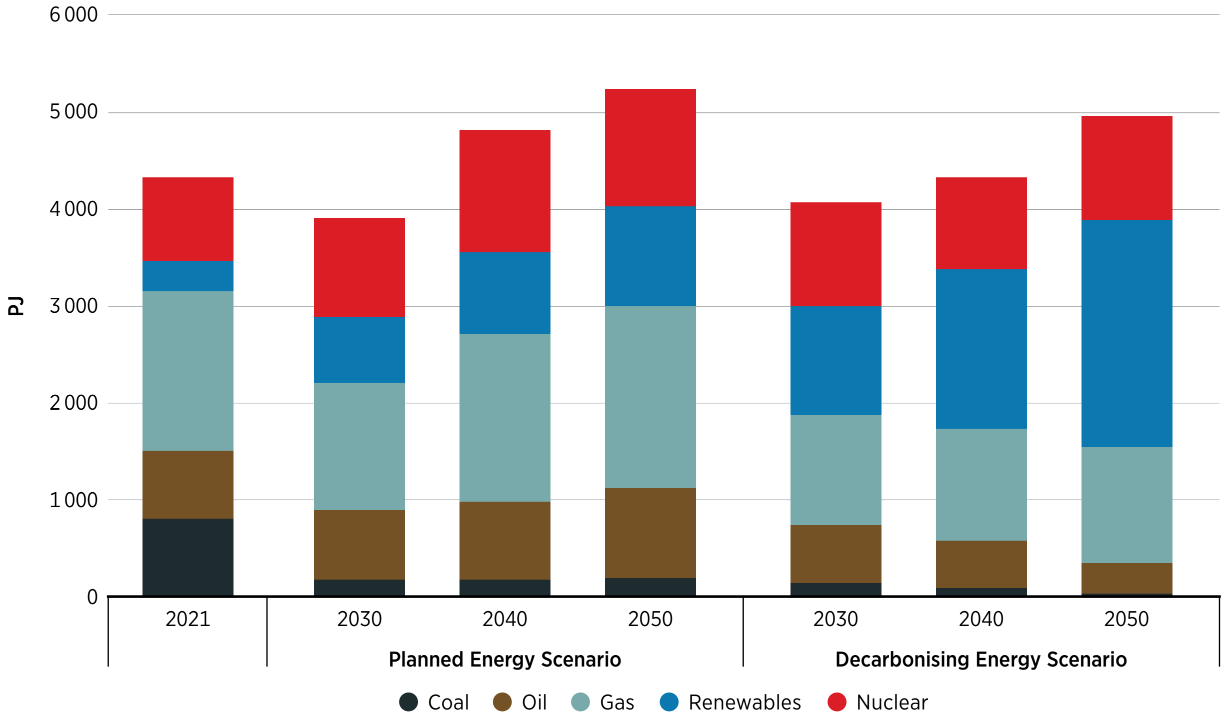


Note: PJ = petajoule.

1.3 TOTAL PRIMARY ENERGY SUPPLY

Total primary energy supply by carrier in both scenarios is shown in Figure 1.5. In 2021, renewables represented a share of 7%, which is expected to increase to 20% in the PES and 51% in the DES by 2050. Nuclear energy is expected to hold an average share of around 24% during the study period in both scenarios, from 20% in 2021, while fossil fuels' share will decrease over time in both scenarios.

Figure 1.5 Total primary energy supply by carrier



Notes: Renewables include direct renewables (*e.g.* bioenergy) and indirect renewables; PJ = petajoule.

The share of fossil fuels in primary energy supply decreases by 2050 in both scenarios, reaching 59% and 34% respectively, from 73% in 2021. Natural gas dominates the fossil fuel supply in the region making up 37% and 26% of the total primary energy supply in the PES and DES by 2050, respectively. Renewable energy is responsible for about one-fifth of the primary supply in the PES 2050. The share of renewable energy in the primary energy supply in 2050 is more apparent in the DES, where it is 51% (Figure 1.5). Despite the major efficiency improvements delivered in the DES by 2050, the primary energy requirements do not differ as much as one might expect, owing largely to the scale of green hydrogen (and derivative fuels) production for export in the DES 2050 from the EaP, as discussed in Chapter 5.

1.4 ENERGY TRANSITION INDICATORS

Following, the KPIs for the EaP countries, electrification of end-use sectors is paramount for decarbonisation in the EaP countries, as elsewhere. Decarbonisation is measured using performance indicators. The key performance indicators (KPIs) used here are the same as in IRENA's *World Energy Transitions Outlook* (IRENA, 2024). They are shown in Table 1.1.

Table 1.1 Key performance indicators: Eastern Partnership

	HISTORICAL	PLANNED ENERGY SCENARIO			DECARBONISING ENERGY SCENARIO		
	2021	2030	2040	2050	2030	2040	2050
KPI.01 RENEWABLES (POWER)							
Renewable energy electricity generation (TWh/yr)	35	68	91	132	92	200	331
Renewable energy share in electricity generation (%)	17%	35%	33%	43%	41%	62%	69%
Renewable energy installed capacity (GW)	23	32	41	60	46	91	142
Renewable energy share in installed capacity (%)	30%	48%	56%	64%	59%	74%	81%
KPI.02 RENEWABLES							
Renewable energy share in final energy consumption (%) - direct + indirect	8%	15%	14%	16%	22%	32%	44%
Renewable energy share in final energy consumption (%) - direct only	5%	7%	6%	5%	12%	12%	12%
Modern use of bioenergy (EJ)	0.2	0.4	0.4	0.4	0.5	0.6	0.8
KPI.03 ENERGY INTENSITY							
Energy intensity annual improvement rate (%)	2.4%	2.3%	2.1%	2.0%	2.8%	2.3%	1.8%
KPI.04 ELECTRIFICATION OF END-USE SECTORS (DIRECT)							
Electricity's share in TFEC (%)	20%	23%	24%	25%	24%	34%	46%
KPI.05 CLEAN HYDROGEN AND DERIVATIVES							
Production of clean hydrogen (Mt)	0	0.2	0.3	0.6	0.3	1.8	4.1
KPI.06 CCS, BECCS AND OTHERS							
Energy and process CO_2 captured from CCS, BECCS and other removal measures (Mt)	0	0	<1	<1	3	16	32

Notes: Indirect renewables' share includes direct use of renewables (bioenergy, solar and geothermal); and indirect renewables (renewable electricity, hydrogen and district heating). BECCS = bioenergy with carbon capture and storage; CCS = carbon capture and storage; CO_2 = carbon dioxide; DES = Decarbonising Energy Scenario; EJ = exajoule; GW = gigawatt; KPI = key performance indicator; Mt = million tonnes; PES = Planned Energy Scenario; TWh/yr = terawatt hours per year; TFEC = total final energy consumption.

The electricity share reaches 24% by 2030 and 46% by 2050 in the DES compared to 23% and 25% in the PES for the same years. This is a result of the increasing use of electric vehicles for road and freight transport, the electrification of heating services in the buildings sector, and the electrification of low-temperature industrial processes.

Energy intensity eases in both scenarios owing to measures taken to raise energy efficiency. The annual improvement rate in the DES is 2.8% by 2030 and 1.8% by 2050, while in the PES it is 2.3% and 2% for the same years. The efficiency measures that account for the difference between the scenarios in energy intensity include the shift to electric vehicles, improvements in buildings' thermal insulation, more efficient electrical appliances, and energy-efficient industrial processes. The drop occurs despite the increase in the region's per capita gross domestic product (GDP). That said, it becomes increasingly difficult to deliver efficiency gains once the most advantageous measures are taken in earlier years, a phenomenon reflected in the reduction of the annual rate of improvement in the DES over time.

The share of bioenergy will grow, reaching 10% of final energy consumption in the EaP region by 2050 in the DES, as bioenergy is used to meet energy demand to heat buildings and to power industry, aviation and shipping, as well as to supply green gases to generate electricity. Import-export dynamics will play a crucial role in balancing supply and demand in the power sector, with significant bi-directional flows being needed for effective power system operation.

In the EaP's power sector, both the PES and DES are expected to show significant growth in renewable electricity generation and installed capacity. Under the PES, renewable electricity generation increases from 35 terawatt hours (TWh) in 2021 to 132 TWh by 2050, with the share of renewables in electricity generation rising to 43% by 2050. Installed renewable capacity grows from 23 GW to 60 GW, representing 64% of total capacity by 2050. The DES outlines a more ambitious trajectory, with renewable electricity generation reaching 331 TWh and its share rising to 69% of total power generation by 2050. Renewable installed capacity increases more than six-fold to 142 GW in the DES, accounting for 81% of total capacity by 2050. This makes clear the crucial role of accelerated deployment of renewables in achieving deeper decarbonisation of the power sector under the DES.

These regional figures reflect a wide range of national trajectories. Differences in natural resource potential, investment levels, and infrastructure development mean that progress will vary considerably from country to country. Ukraine accounts for the largest share of renewables capacity in the DES, with projections reaching nearly 20 GW of solar and 32 GW of onshore wind by 2050. Azerbaijan also sees strong growth, particularly in offshore wind, while Armenia, Georgia, and the Republic of Moldova expand at a slower pace, shaped by local conditions and policy priorities.

The composition of the power mix also varies. Nuclear energy, for example, plays a role in both Ukraine and Armenia, the two countries in the region with operating nuclear power plants. Ukraine has by far the larger nuclear fleet, with 14.6 GW projected in 2050, while Armenia maintains a consistent level of around 0.4 GW over the outlook period. Fossil fuel use declines overall, but natural gas remains a notable part of the mix in countries like Azerbaijan and Armenia. Coal is entirely phased out by 2050 in the DES; even in the PES, coal accounts for only a small fraction of capacity by 2050.

Hydrogen and its derivatives, such as ammonia and methanol, are projected under the DES to account for around 1% of final energy consumption in the EaP by 2050. Securing sustainable water resources for electrolysis and low-emission CO_2 sources for synthetic fuel production will be essential. These resource requirements could become significant constraints if not addressed through integrated infrastructure and good planning. Total clean hydrogen production (electrolytic, biological and blue hydrogen) is expected to reach 4.1 million tonnes (Mt) by 2050 in the DES, far exceeding the domestic demand of 1.7 Mt, enabling exports of up to 2.5 Mt. In the PES, clean hydrogen production reaches 0.6 Mt by 2050, while domestic hydrogen demand reaches 1.2 Mt.

These are supported by emerging hydrogen strategies in the EaP, and by a growing global need for imports of hydrogen-based commodities. This export potential in the DES is driven by the growth of electrolyser capacity and an accompanying growth in the share of green hydrogen, which reaches 51% of output by 2050 (including both electrolytic and biological based hydrogen). With the European Union expected to import up to 44% of its hydrogen energy needs (both gaseous and derivative fuels, including aviation and marine bunkers) by 2050 (IRENA, 2025a), the EaP is well positioned as a nearby supplier. This is particularly true of derivatives like ammonia and methanol, which are easier to transport than pure hydrogen. However, the development of hydrogen export opportunities, along with other commodities such as steel, fertilisers and electricity, will need to align with the EU's Carbon Border Adjustment Mechanism, a climate policy designed to prevent carbon leakage (European Commission, 2025a). Hydrogen classified as a Renewable Fuel of Non-Biological Origin (RFNBO) must also comply with specific requirements set out in the Delegated Acts of the Renewable Energy Directive (RED II/III) to be eligible for recognition within the EU market.

1.5 MEASURES AND ACTIONS SUGGESTED

Reaching the emissions reduction projected in the DES requires the implementation of a set of measures and actions that are described in Table 1.2.

Table 1.2 Summary table of key policies and actions

OUTCOMES	MEASURES AND ACTIONS SUGGESTED	IMPACT
Electrification of end-use sectors	Set binding targets for electrification of transport, heating, and industrial processes	Increase electricity's share in final energy consumption (FEC) to 46% by 2050
Energy efficiency	Implement mandatory efficiency standards for buildings, appliances, and industry	Achieve energy intensity annual improvement rate of 2.8% by 2030 and 1.8% by 2050
Renewable energy deployment	Accelerate deployment of solar photovoltaic, wind (onshore/offshore), and bioenergy; support auctions and power purchase agreements Create a robust supply chain at the national and regional levels that can satisfy the growth of renewable energy penetration	Enable renewable electricity share of 69% by 2050 and direct and indirect renewable energy share in FEC of 47%
Power sector investment	Mobilise EUR 292 billion cumulatively (2025–2050); develop bankable project pipelines	Finance the expansion of 142 GW of renewable capacity and grid upgrades
Climate policy framework	Establish national and sectoral decarbonisation roadmaps with clear milestones and interim targets	Provide long-term policy certainty and investor confidence
Monitoring and verification	Develop robust measurement, reporting and verification (MRV) systems for all sectors	Track progress and enforce accountability for emissions and energy performance goals
Cross-border co-operation	Promote regional infrastructure and inter-connection projects	Lower costs, improve system flexibility, and unlock international financing
Green finance mechanisms	Leverage development banks and public–private partnerships to de-risk investments	Expand access to concessional finance and blended capital for renewable and efficiency projects
Public awareness and local action	Engage sub-national actors and raise awareness of benefits of clean energy transition	Support social acceptance and effective implementation at the local level

Notes: PV = photovoltaic; PPAs = power purchase agreement; EUR = euro; MRV = measurement, reporting and verification; FEC = final energy consumption; GW = gigawatt.

2

TRANSPORT

This chapter presents the outcomes, findings and messages of the transport sector analysis for the Eastern Partnership (EaP) countries, addressing questions such as:

1. What is the status of the decarbonisation of transport in the region?
2. Are the current strategies and measures adequate to significantly reduce emissions from the sector by 2050, with the aim of approaching net zero?
3. What additional measures could be implemented to further decarbonise the transport sector?

2.1 REGIONAL CONTEXT

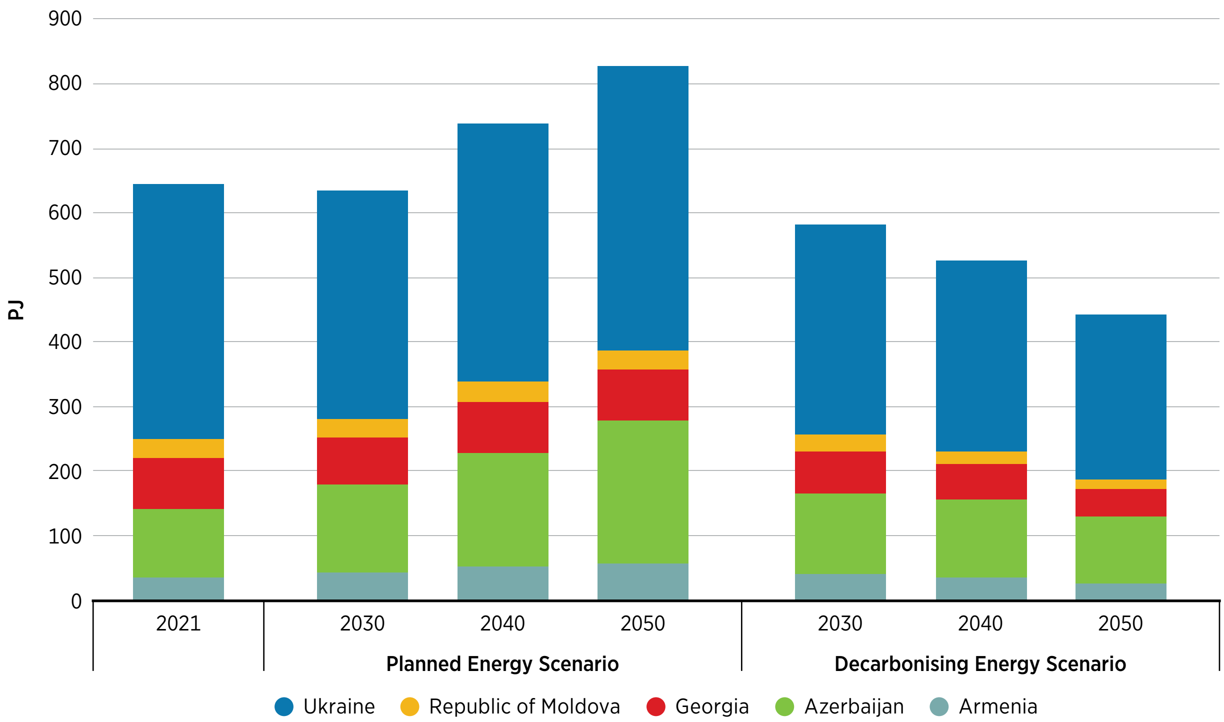
Efficient mobility of people and goods is essential to the functioning of modern society and economy. In the EaP countries analysed, the transport sector currently relies heavily on fossil fuels, which represent about 97% of the sector's final energy consumption, and alone account for around a fifth of the energy sector's greenhouse gas emissions. Passenger and freight land transport activity is expected to increase similarly in both scenarios in the run-up to 2050, reaching 505 billion passenger-kilometres (p-km) and 490 tonne-kilometres (t-km) – 50% and 90% higher than the 2021 levels.

Decarbonisation of the sector is therefore key to reducing GHG emissions and meeting the targets of the Paris Agreement. Efforts have already been made to project transport needs, and Armenia has set electromobility targets for 2030 (Government of Armenia, 2023, 2024; USAID, 2022). An electromobility draft plan has been developed in Azerbaijan, with electric vehicles targets defined in the short term (Government of Azerbaijan, 2024). Georgia, the Republic of Moldova and Ukraine have also included specific transport sector targets in their Integrated National Energy and Climate Plans with the aim of increasing biofuels blending and the number of EVs in the fleet (Government of Georgia, 2023; Government of the Republic of Moldova, 2023; Government of Ukraine, 2024b).

Transport energy demand projections for the region depend highly on the measures used in Ukraine, which represents more than half of all demand over the study period, and Azerbaijan, which represents about a quarter of demand (Figure 2.1).

Demand is expected to grow in the Planned Energy Scenario (PES) from around 640 PJ in 2021 to around 830 PJ by 2050, while in the Decarbonising Energy Scenario (DES) it is expected to decrease to around 440 PJ by 2050, while maintaining the same activity level. Energy efficiency gains derived from replacing internal combustion engine vehicles with EVs account for the lower demand.

Figure 2.1 Domestic transport: Final energy demand, by country

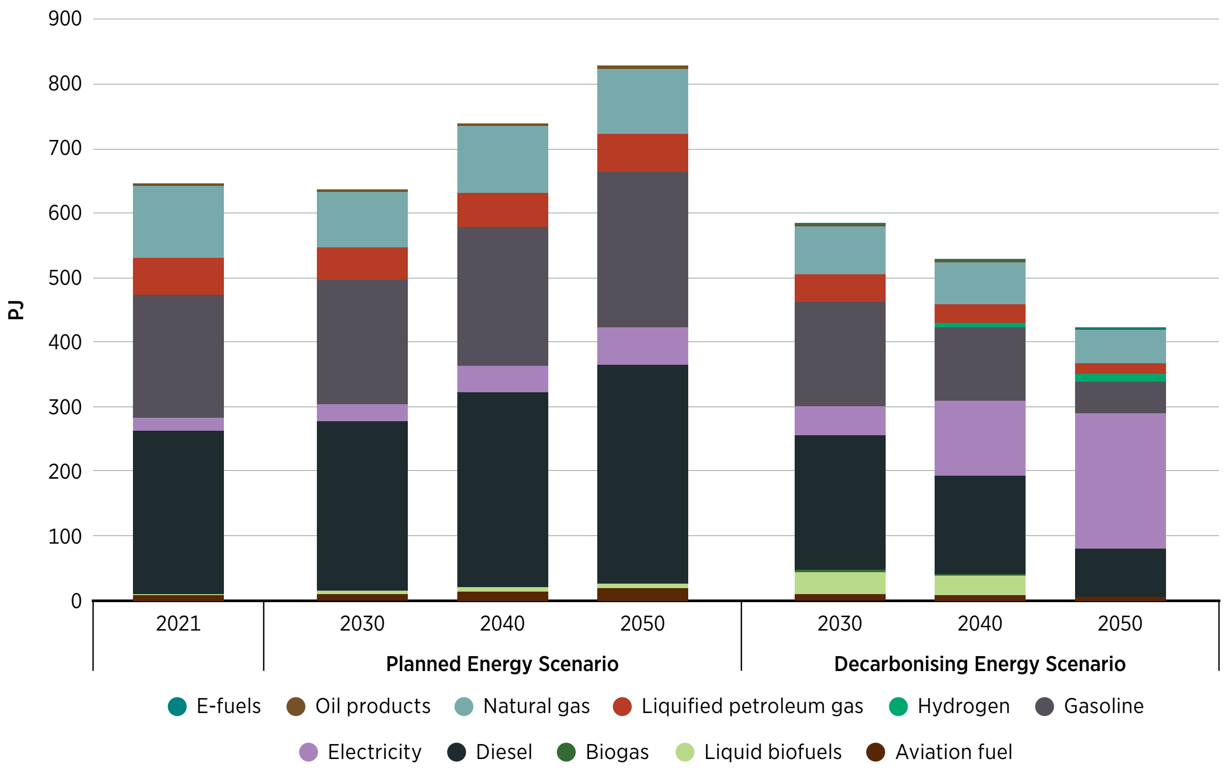


Note: PJ = petajoule.

2.2 OVERVIEW OF THE TRANSPORT SECTOR

The transport sector would undergo a complete transformation under the DES, as shown in Figure 2.2. Fossil fuel derivatives accounted for 97% of the sector's final energy consumption in 2021. In the PES, that share is expected to drop to 92% by 2050, mainly because of an increase in the share of electricity (from 3% to 7%). However, total demand is expected to increase by almost 30% by 2050 over 2021. In the DES, by 2050 total demand would decrease by approximately 30% relative to 2021, and electricity would become the main energy carrier, with a share of 48%.

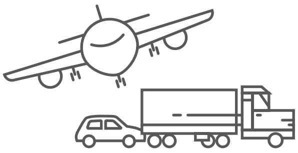
Figure 2.2 Domestic transport: Final energy consumption by carrier



Notes: "Oil products" refers to those used in shipping. "E-fuels" refers to those used in the aviation sector. Final energy demand for domestic transport includes pipeline transport; LPG = liquefied petroleum gas; PJ = petajoule.

The main performance indicators for the transport sector, presented in Table 2.1, further exemplify the transformation that the DES represents. That transformation leads to a CO_2 emissions reduction of around 75%, reaching 10 million tonnes of carbon dioxide ($MtCO_2$) by 2050 from 38 $MtCO_2$ in 2021. The main driver for the drop is the reduction in fossil fuels use owing to electrification of the fleet. Electricity demand increases from 20 PJ in 2021 to 210 PJ by 2050 in the DES.

Table 2.1 Transport: Key performance indicators

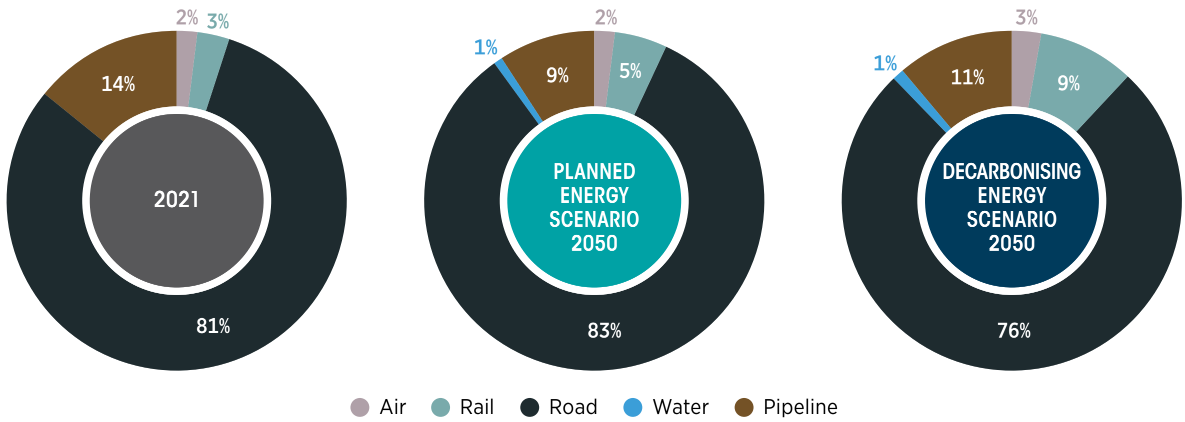


	HISTORICAL	PLANNED ENERGY SCENARIO			DECARBONISING ENERGY SCENARIO		
	2021	**2030**	**2040**	**2050**	**2030**	**2040**	**2050**
KPI.02 RENEWABLES							
Biofuels share in transport FEC (%)	0.3%	0.7%	0.8%	0.9%	6.5%	6.2%	4.8%
Direct and indirect renewable energy share in transport FEC (%)	0.8%	2.2%	2.9%	4.4%	9.6%	20%	39%
KPI.03 ENERGY INTENSITY							
Transport - FEC (EJ)	645	640	740	830	580	530	445
KPI.04 ELECTRIFICATION OF END-USE SECTORS (DIRECT)							
Share of Electricity in transport FEC (%)	3.0%	4.2%	5.6%	7.0%	7.5%	22%	48%
Electric and plug-in hybrid light passenger vehiles (million units)	0.1	0.6	1.6	3.3	1.4	5.5	11.5
Public EV chargers (thousand units)	12	37	62	125	85	219	458
KPI.05 CLEAN HYDROGEN AND DERIVATIVES							
Clean hydrogen and derivatives share in transport FEC (%)	0.0%	0.0%	0.0%	0.0%	0.0%	1.3%	3.2%
EMISSIONS							
CO_2 emissions ($MtCO_2$/year)	38	38	43	49	31	22	10

Notes: FEC = final energy consumption; EJ = exahoule; EV = electric vehicle; CO_2 = carbon dioxide; $MtCO_2$ = million tonnes of carbon dioxide. Pipeline transport energy demand is included for the calculation of the KPIs.

Figure 2.3 presents the modal shares in energy consumption for domestic transport in 2021 and 2050 under the PES and DES. During the entire study period, road transport is the predominant transport mode, representing a share of 81% in 2021. By 2050, this share remains at the same levels in the PES and decreases to 76% in the DES. The further reduction in the DES is due to efficiency gains from replacing ICE vehicles with EVs, and the modal shift from this transport mode to rail. Pipeline transport[1] represents a considerable share of the consumption during the study period, Geogia and Ukraine being the countries with highest consumption.

Figure 2.3 Domestic transport: Modal shares in energy consumption



Road transport

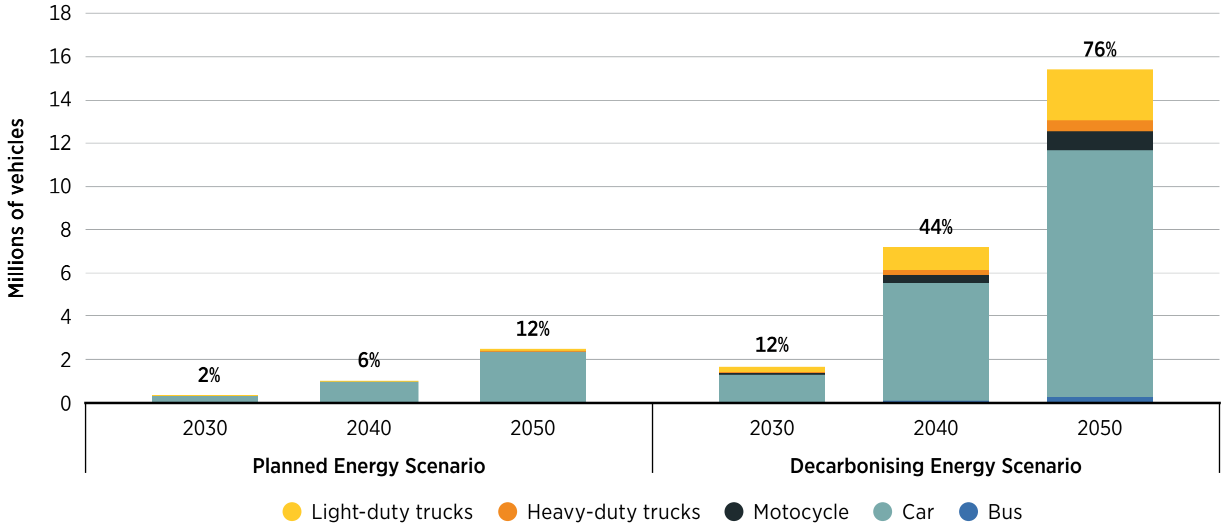
Road passenger activity level is expected to increase by 2050 with respect to 2021 by around 46% and 42% in the PES and DES respectively. Road freight activity is also expected to increase by 93% in the PES and 42% in the DES by 2050 with respect to 2021. The increase in both passenger and freight transport is lower in the DES due to a shift to rail transport. With the increase in activity, congestion and emissions are also expected to rise.

The main decarbonisation pathway to lower road transport emissions is electrification of the fleet. Armenia, Georgia, the Republic of Moldova and Ukraine currently depend heavily on imported oil products. By electrifying their vehicle fleets, these countries could not only lower emissions, but also enhance their energy security, provided the electricity comes from domestic sources, and improve urban air quality. The promotion of car sharing and use of public buses could reduce congestion and emissions, especially in urban areas.

Electrification is also expected to be the main decarbonisation pathway for road freight transport, with electric trucks replacing small and large trucks equipped with internal combustion engines. The stock of EVs in the PES and DES is presented in Figure 2.4. The electrification targets contained in current plans, strategies and other documents are not enough for a deep electrification of the fleet in the EaP countries. Further efforts, as in the DES, are needed.

[1] *Pipeline transport includes the quantities of fuels used as energy in the support and operation of pipelines transporting gases, liquids, slurries and other commodities.*

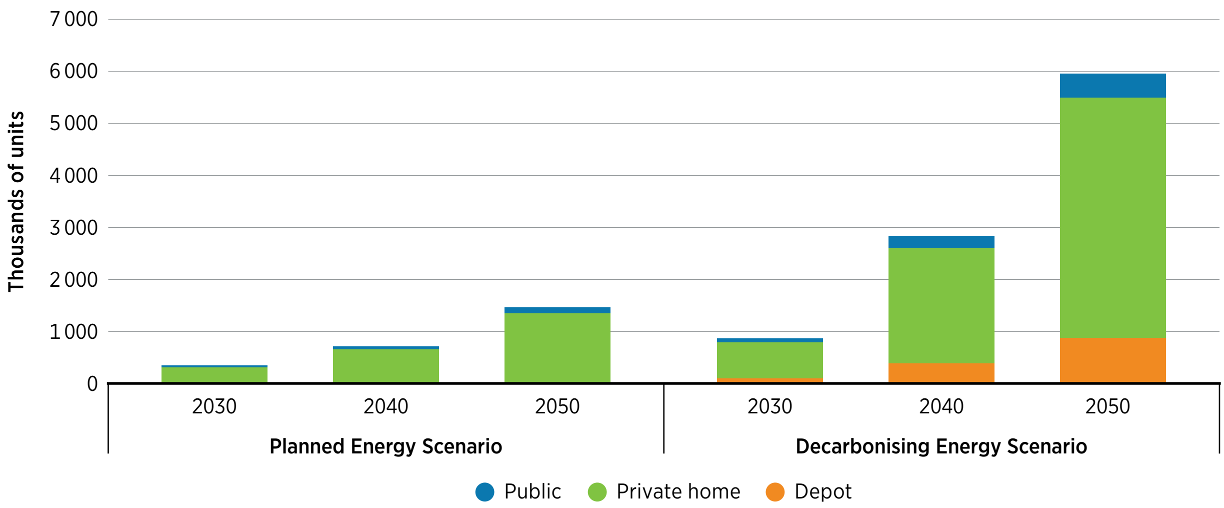
Figure 2.4 Electric vehicle stock and shares in stock, by vehicle type



Note: Percentages illustrate shares in stock.

The lack of appropriate charging infrastructure is an obstacle for the adoption of EVs. Fleet electrification depends on the development of a network of charging stations. The choice of chargers will depend on the EV technology and its specific uses. Figure 2.5 presents the number of chargers, by type, needed during the study period in the PES and DES.

Figure 2.5 Electric vehicle charging points by type



Home charging points are the most common type. However, it is assumed that as private cars sales increase, they may also be charged at work or at slow public charging stations. Fast chargers are also assumed to be installed on highways to cover cars' charging needs during long-distance trips.

Light-duty vehicles and urban buses are expected to operate on predictable or fixed routes in cities and to be charged mostly at depot charging stations. Heavy-duty trucks are also expected to be charged at depot charging stations when loading or unloading, but also on highways during long trips. Ultra-fast-charging stations (*e.g.* MW level charging) networks and corridors will be needed for this purpose.

Charging patterns of private cars and commercial EVs differ. Private electric cars represent a larger number of vehicles whose charging needs will be geographically distributed and impose a lower electricity demand.

Such vehicles could provide flexibility to the distribution grid, as they are expected to be parked most of the time. Commercial EV charging needs are expected to be geographically concentrated and to impose higher electricity demand. Although commercial EVs are expected to spend less time parked, their use patterns are more predictable than those of private vehicles; therefore, they, too, could provide flexibility services.

To support a fair transition to electric mobility, it is essential to analyse EV charging needs and usage patterns at the local level, ensuring that all citizens have affordable and equitable access. EV deployment can be combined with the development of public transit system, utilising financial resources from multilateral development banks (IRENA, 2025b).

The use of hydrogen-based buses and heavy-duty trucks in niche applications complements the decarbonisation of road transport, as do biofuels and biomethane. Agricultural and municipal waste could be used as feedstock for the production of biomethane, representing an opportunity to exploit the domestically available low-carbon fuel.

Rail transport

Rail transport is an efficient way of moving people and goods. Passenger rail transport is expected to reach 29 billion p-km and 35 billion p-km in the PES and DES, respectively, by 2050, up from 16 billion p-km in 2021. Freight rail transport is also expected to increase during the study period reaching 330 billion t-km and 354 billion t-km by 2050 in the PES and DES, respectively, from 180 billion t-km in 2021. By 2050, rail passenger and freight activity are higher in the DES than in the PES. This is due to the modal shifts from cars and aviation to passenger rail and from heavy-duty trucks to freight rail.

In 2021, electricity accounted for 93.5% of rail transport's energy demand. With network electrification, rail transport has the potential to contribute to the decarbonisation of the region's transport sector. Azerbaijan has shown interest in creating a green corridor along the multimodal trade route that connects China to Europe (REPORT, 2024). In Ukraine, railways are already the dominant means of transporting goods.

Aviation

Domestic aviation is present in Azerbaijan, Ukraine and Georgia, representing a 3.9%, 1.6% and 0.05% share of energy consumption for transport in 2021. Despite these small shares, the DES includes efforts to decarbonise the sector by increasing the use of bio-jet in aviation fuels and by assuming a modal shift towards rail transport.

Demand for international aviation is also considered in the analysis. Demand rises from 29 PJ in 2021 to 72 PJ by 2050 in both scenarios. As in the case of domestic aviation, the main decarbonisation pathway in the DES is the blending of bio-jet, with the aim of contributing to the International Civil Aviation Organisation's aspiration to achieve net-zero emissions in international aviation by 2050 (ICAO *et al.*, 2023).

Shipping

Domestic shipping represented 0.5% of transport energy consumption in the EaP countries in 2021, being most relevant for Azerbaijan, where shipping represented a 2.3% share of energy consumption. The main decarbonisation pathway considered in the DES is the introduction of biofuels.

International shipping demand is also considered for Azerbaijan and Georgia. Demand in 2021 was 1.3 PJ and is expected to reach 3.1 PJ by 2050 in both scenarios. Despite representing a small share of demand, biofuels contribute to the International Maritime Organisation's aspirational goal of reaching net-zero emissions from international shipping by 2050 (IMO, 2025).

2.3 KEY ACTIONS AND PRIORITIES IN TRANSPORT

Table 2.2 summarises the measures considered in the DES by mode and type. These measures can be used as a reference for the efforts that must be made to reach the emissions reduction projected in the DES.

Table 2.2 Transport: Measures considered in the Decarbonising Energy Scenario, by mode

MODE	MEASURES
Road	**Biofuels blending** • Biodiesel blending in diesel: 10% by 2030 and 2050[1] • Bioethanol blending in gasoline: 6% by 2030 and 2050[1] • Biomethane blending in natural gas: 18% by 2030 and 22% by 2050
	Electric and hydrogen vehicles shares in stock[2] • Electric cars, motorcycles and light duty vehicles: 85% share by 2050 • Electric buses and heavy-duty vehicles: 70% share by 2050 • Hydrogen based buses and heavy-duty vehicles: 10% share by 2050
	Energy efficiency • Specific fuel and electricity consumption decreases are built into both scenarios to reflect technology improvements • Car sharing initiatives lessen distance travelled by 5% and increases vehicle's occupancy • More efficient goods delivery is represented by increase in payload, resulting in a 5% drop in the distance travelled by trucks • Modal shift from cars to rail, resulting in a 20% increase in rail p-kms and a decrease of the distance travelled by cars • Modal shift from heavy-duty trucks to rail, resulting in an increase in rail activity averaging 40% for Armenia, Azerbaijan, Georgia and the Republic of Moldova, and a decrease of distance travelled by heavy-duty vehicles. In Ukraine, a rail activity increase of 8% by 2050 was assumed, resulting in an 8% decrease in distance travelled decrease by heavy-duty vehicles
Rail	**Energy efficiency** • Improvements in specific fuel consumption are considered for passenger and freight rail transport • Modal shift towards rail from road increases passenger and freight rail activity by 2050 • Modal shift towards passenger rail from aviation represented by a 10% p-km decrease of passenger aviation by 2050
	Electrification • Passenger rail transport electrification: by 2050, all passenger rail transport is electrified • Freight rail transport electrification: by 2050, all freight transport is electrified in all countries. Electricity shares were already 90% in 2021, except in the Republic of Moldova, where it was zero. The Republic of Moldova reaches an electricity share of 50%
Aviation	**Biofuel and e-fuels blending** • In domestic aviation: 40% biofuel blending and 10% e-fuels blending by 2050 • In international aviation: 55% biofuel blending and 15% e-fuels blending by 2050
	Energy efficiency • Annual improvements of 1% in specific fuel consumption
	Modal shift • By 2050, aviation p-kms in the DES are 10% lower than in the PES due to modal shift to rail

Shipping	**Biofuels blending** • Domestic shipping: 50% biofuel blending by 2050 • Biomethane blending in natural gas: 18% by 2030 and 22% by 2050 • International shipping: 70% biofuel blending by 2050	
	Electrification • Domestic shipping: electricity reaches a share of 5% by 2050, reflecting the assumption that small boats are electrified	

[1] *Biodiesel and bioethanol blending in Georgia reaches 12% by 2050 as defined in their National Energy and Climate Plan.*

[2] *Electric and H_2 vehicles in Ukraine reach lower shares by 2050 following the lower GDP per capita projected and therefore lower purchase power. Electric cars, motorcycles and light-duty vehicles reach 70% by 2050, electric buses and heavy-duty trucks 60% and H_2 buses and heavy-duty trucks 5%*

Notes: p-km = passenger kilometers; PES = Planned Energy Scenario; DES = Decarbonising Energy Scenario.

Table 2.3 presents the measures and actions recommended for reaching the targets presented in the table above in the Decarbonising Energy Scenario.

Table 2.3 Transport: Key actions and priorities

OUTCOMES	MEASURES AND ACTIONS SUGGESTED
Fleet electrification	• Adoption of medium- and long-term strategy and action plans and targets for EV deployment and charging infrastructure • Financial incentives for developing an EV charging network (in cities and highways), standardising batteries and charging processes, and mandating a certain ratio of EV chargers to parking spaces, as well as promoting pre-cabling for EV chargers at new constructions and renovated buildings • Incentivising EV charging during times of high mismatch between supply (*e.g.* through time-of-use tariffs) and demand and use of vehicle-to-grid technologies to support grid stability • Zero- or low-emission zones in cities and benefits for EV users *i.e.* free parking • Promoting 100% EV for public fleets • Investing in public charging networks • Transition strategy for workers currently employed in the traditional automotive industry who may require training and upskilling
Energy efficiency improvements in specific fuel consumption	• Optimised driving techniques to enhance vehicle efficiency, decrease total energy consumption, and contribute to higher renewable energy integration by reducing overall energy demand
Occupancy and payload increase in cars and trucks respectively	• Car-sharing schemes and efficiency programmes • Parking restrictions and benefits for cars with two or more travellers *i.e.* use of high-occupancy lanes
Modal shift	• Increase in rail transport services and modernisation and expansion of the rail network as needed to accommodate new demand • Incentives for passengers to use rail transport • Promotion of inter-modal mobility
Biofuel blending	• Sustainable biofuels production where local potential exists • Partnerships with biofuels exporting countries
Hydrogen based vehicles and e-fuels blending	• Financial incentives for acquisition of hydrogen-based heavy-duty vehicles for niche applications

Notes: ICE = internal combustion engine; EV = electric vehicle; V2G = vehicle to grid.

3

INDUSTRY

This chapter presents the main outcomes, findings and messages of the industry sector analysis for the Eastern Partnership (EaP) countries, addressing key questions such as:

1. What is the status of industry in the region, and where will industry stand in 2050 based on current policies?
2. How can existing directives, plans and measures be enhanced to deliver net-zero by 2050?
3. What should policy makers focus on?

3.1 REGIONAL CONTEXT

Industry in the EaP countries is diverse and driven by historical context, geopolitical influences and to some extent, integration with the European Union. Industry in Ukraine is dominated by its iron and steel and chemicals. Azerbaijan's chemical sector made it the region's second-highest energy consuming country in 2021. Together, the two countries made up more than 90% of the region's industrial consumption in that year. The iron and steel industry is strongest in Ukraine and Georgia, both of which have integrated iron and steel production facilities, whereas Armenia, the Republic of Moldova and Azerbaijan produce steel only. Iron and steel account for more than 43% of the sector's consumption in the region, followed by chemicals with about 26% and other industrial sectors with 22%.

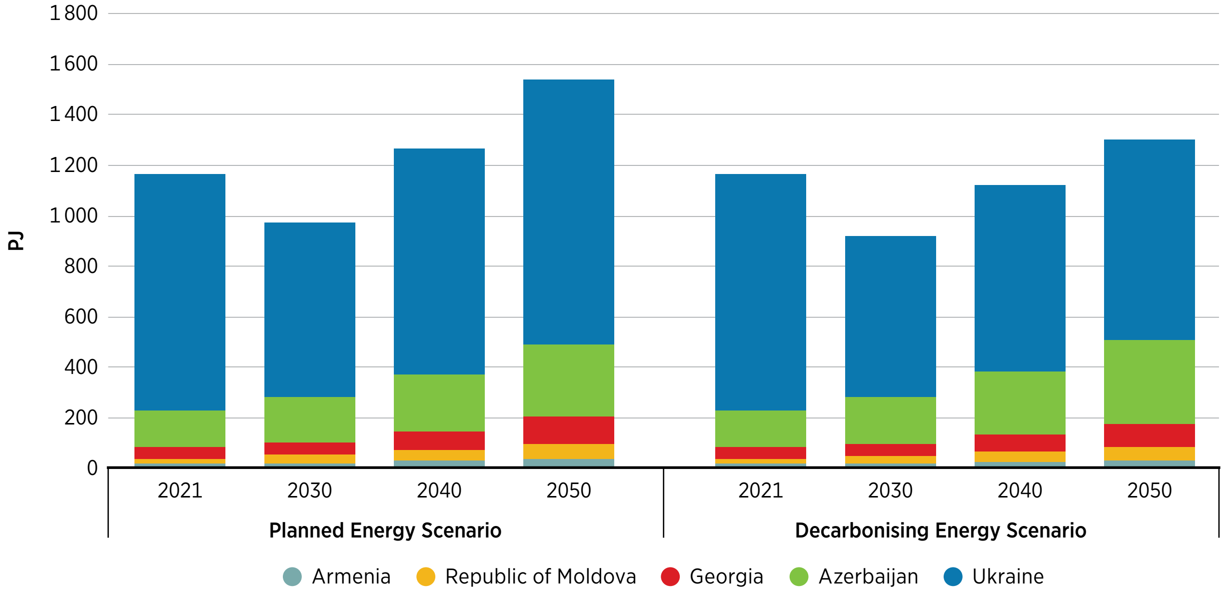
Under its National Energy and Climate Plan, Ukraine has developed a National Economic Strategy to utilise its competitive advantages to create new production capacities by stimulating innovative activities (Government of Ukraine, 2024b). The strategy highlights the high costs and time required to connect production capacities to the power grid, the low level of research funding and the lack of close co-operation between scientific institutions and industrial enterprises. The region as a whole faces similar challenges. Azerbaijan has been using its economic mechanisms in recent years to reduce industry's impacts on climate change, encouraging innovative investment to create industrial parks and special economic zones (Government of Azerbaijan, 2023). Azerbaijan published a National Hydrogen Strategic Outlook in 2024, identifying industry as well as aviation and the marine sector, as the focus, while also supporting funds for research and development in hydrogen and in carbon capture utilisation and storage (Republic of Azerbaijan, 2024). Georgia updated its Nationally Determined Contribution in 2023, committing unconditionally to a 35% reduction in its greenhouse gas emissions by 2030, and conditionally to the target of reducing emissions to 50–57% below 1990 levels (Government of Georgia, 2023). The Republic of Moldova has assumed ambitious targets to achieve climate neutrality by 2050. Where available, the country is promoting clean energy technologies and where appropriate, has set national objectives – including long-term targets (2050) for the deployment of low-carbon technologies in energy and carbon-intensive industries (Government of the Republic of Moldova, 2023). Armenia's long-term low-emission development strategy envisions the use of alternative building materials to reduce cement, the circular economy to decrease waste and the introduction of low carbon production technologies combined with carbon capture and storage (CCS) as priorities for industry (Government of the Republic of Armenia, 2023). Until 2021, EaP countries were supported by the Ready to Trade project, which aims to help participating states integrate into global value chains, and thereby access new markets, with a focus on the EU.

3.2 OVERVIEW OF THE INDUSTRY SECTOR

IRENA analysed the decarbonisation pathways for iron and steel, cement, chemicals, and other industries in the region. Although the region has no specific net-zero target for the sector, individual countries have long-term low-emission strategies and are pursuing a green transition through renewable energy, energy efficiency, and sustainable infrastructure. EaP countries have been aligning their industrial policies to the EU's decarbonisation efforts to foster sustainable economic growth and tap access to the green market. Some of the main efforts are to promote renewable energy (including green gases), energy efficiency and investment in green technologies, while adopting EU standards and regulation to the extent possible. Industrial decarbonisation especially for carbon-intensive iron and steel production, will be crucial to increase the region's competitiveness in the market. The Carbon Border Adjustment Mechanism can be used as a policy signal to encourage the region's industry ramp up investment in clean technology to ensure access to European and global markets.

In 2021, EaP's industry consumed 1167 PJ, with Ukraine consuming 939 PJ followed by Azerbaijan and Georgia with 141 PJ and 45 PJ respectively (Figure 3.1). Although its share is falling, Ukraine will continue to dominate the region's industry consumption: 68% by 2050 in the Planned Energy Scenario (PES). Azerbaijan, Georgia, the Republic of Moldova and Armenia will see their consumption growing at an average annual rate of 2.9% between 2021 and 2050.

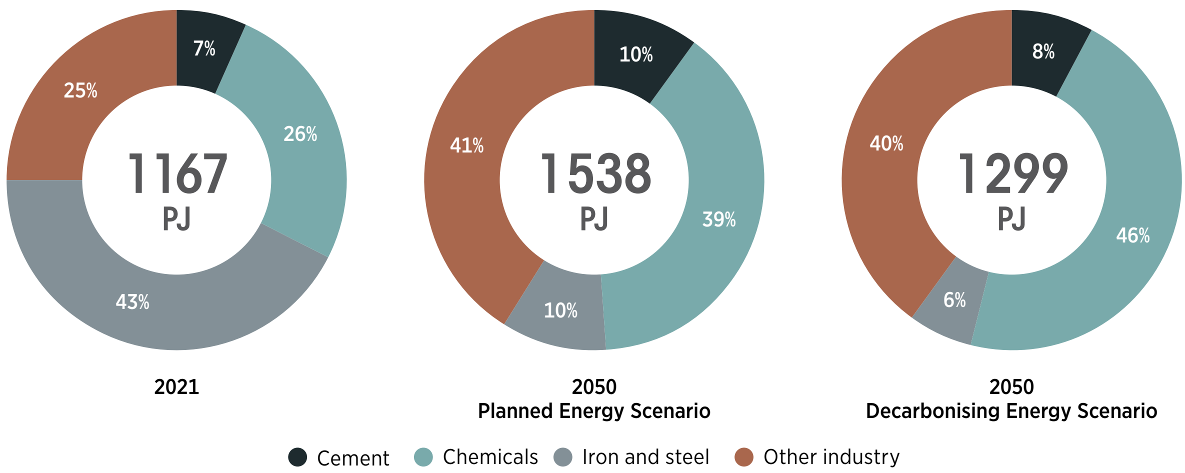
Figure 3.1 Industry: Final consumption of the sector, by country



Note: PJ = petajoule.

Figure 3.2 presents the share of industrial sub-sectors in total final consumption. Iron and steel consumed nearly 499 PJ in 2021. Other industries and chemicals together made up more than 48% of the region's consumption with about 260 PJ and 302 PJ respectively. Industry consumption will drop by about 16% towards 2030 driven chiefly by reductions in iron and steel industry activity; the reductions will reduce its share to just 11% of industrial consumption. Between 2030 and 2050, the industry sector will grow 2.3% annually, reaching 1538 PJ. By mid-century, chemicals take over as the dominant industry sub-sector, making up 39% of the sector's final consumption from about 26% in 2021.

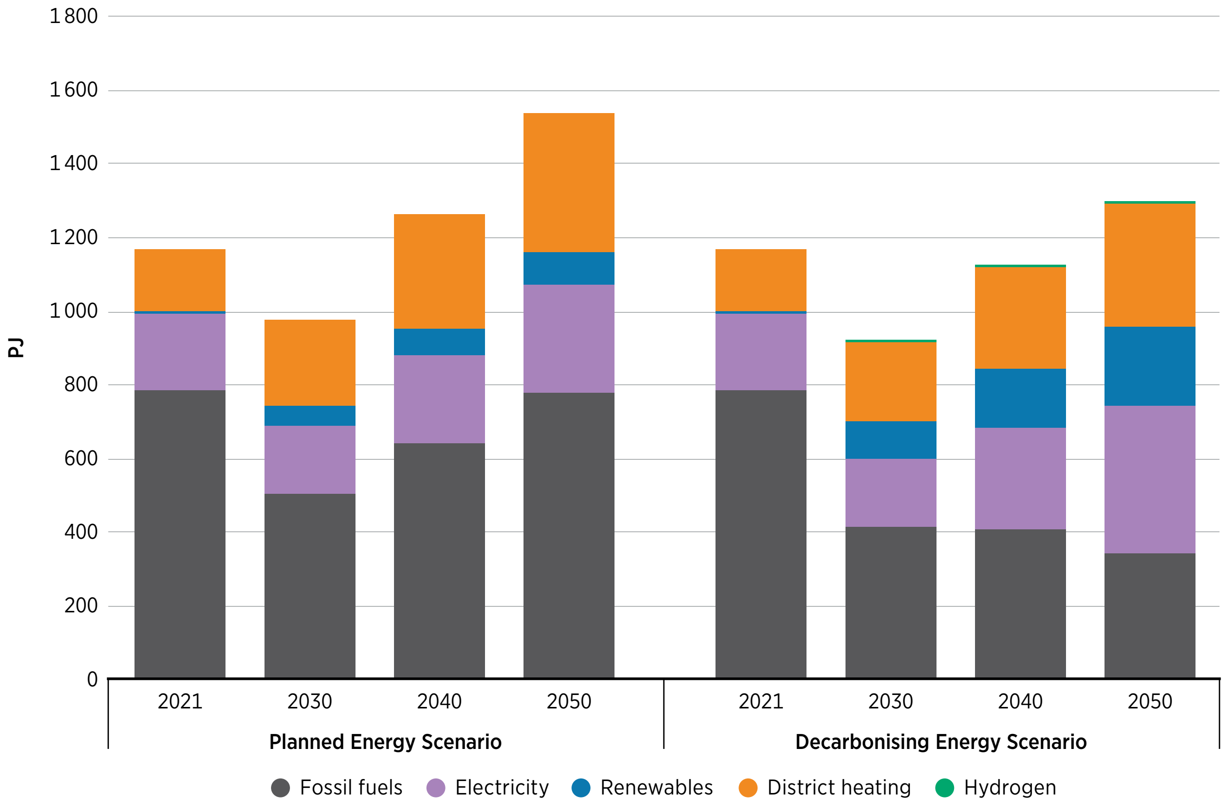
Figure 3.2 Industry: Final consumption, by sub-sector



Note: PJ = petajoule.

The region's industry still relied heavily on fossil fuels in 2021, when they made up nearly 67% of its consumption – including non-energy (Figure 3.3). Electricity made up the second-largest share, driven by "other industries". Utilisation of renewable fuels was minimal in the base year. But driven by the EaP countries' ambition to increase the role of direct renewables in the energy mix, the PES will see renewables' share grow 10% annually in the run-up to 2050, reaching 23 times its 2021 share. Driven by the growing importance of chemicals and other industries over iron and steel, electricity consumption in the PES increases 1.4 times by 2050 over the 2021 level, consuming 290 PJ (80 TWh).

Figure 3.3 Industry: Final consumption, by carrier

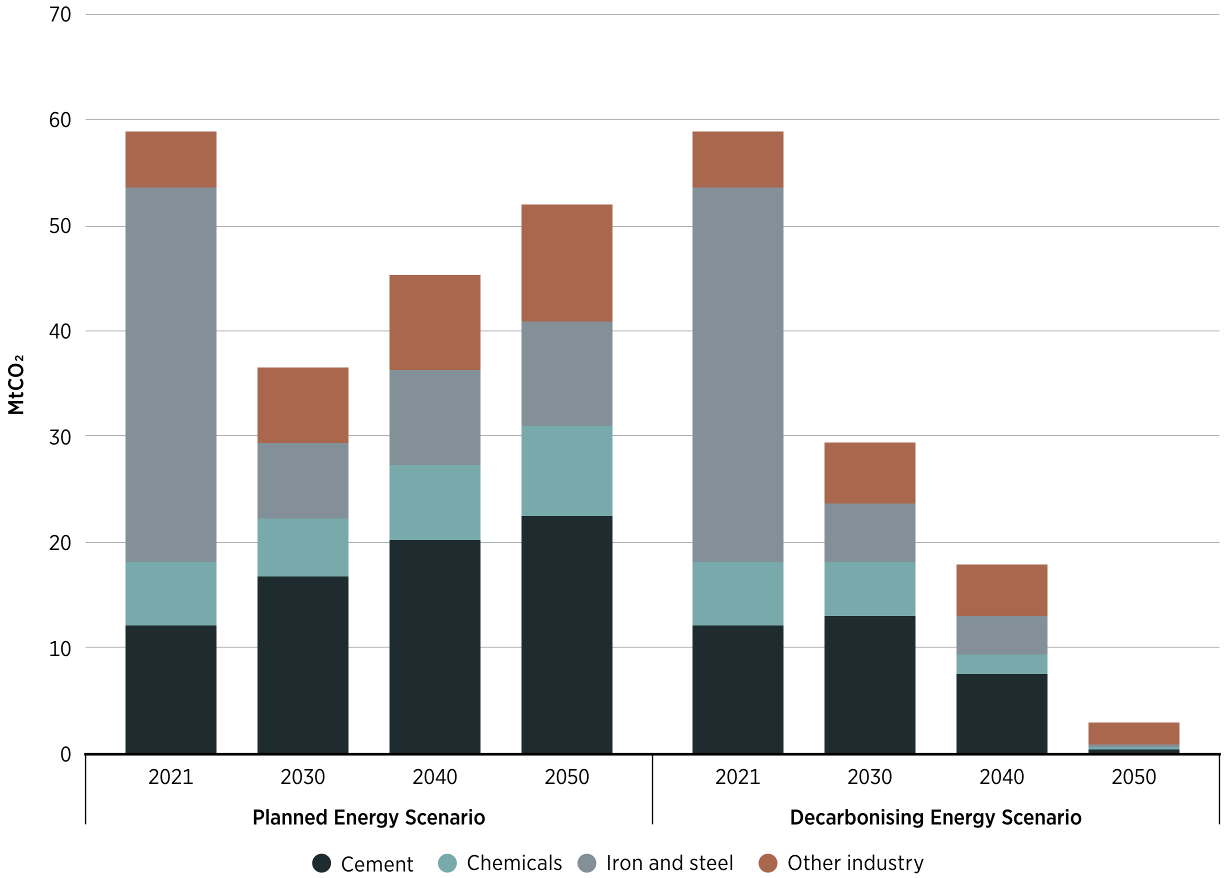


Note: PJ = petajoule.

The Decarbonising Energy Scenario (DES) optimises the decarbonisation effort by implementing low carbon technologies and sustainable infrastructure to the extent possible, including transition towards renewables and energy efficiency. This effort reduces industry's energy consumption in the DES to 1 299 PJ by 2050, about 16% lower than in the PES. The share of fossil fuels plunges to a quarter (342 PJ) of total consumption, just 44% of its 2021. The share of renewables in the DES by 2050 (216 PJ) is more than double the share in the PES in the same year, a 54-fold increase over 2021. Electricity becomes clearly dominant in the DES by 2050, reaching 399 PJ (111 TWh) and making up about one-third of the sector's consumption. The rise is driven by greater electrification of low-temperature industries, as well as implementation of scrap steel production using electric arc furnaces and electrochemical production. By 2050, the transition to low-carbon processes, combined with energy efficiency measures, pushes down energy consumption in iron and steel in the DES to half of its level in the PES. The transition will be driven by increased use of electric arc furnaces, greater use of electrochemical production in the chemical sub-sector, and increased electricity share in other industries.

The PES shows that industrial emissions fall in the short term (to 2030), driven by a drop in emissions in the iron and steel industry, as seen in Figure 3.4. The region's industrial emissions rise again in the approach to 2050, driven by iron and steel production and projected growth in production in other industries. Despite rising consumption from 2021 to 2050 in the DES, especially in Ukraine's and Azerbaijan's chemicals sub-sector (1.5-fold and 2.8-fold increases, respectively), chemical emissions grow by only 1% annually. Cement and other industries show a steady increase in emissions between 2021 and 2050, at an average rate of 2.2%. In the PES, the EaP's total industrial emissions fall 12% by 2050 from 2021.

Figure 3.4 Industry: CO_2 emissions by sub-sector

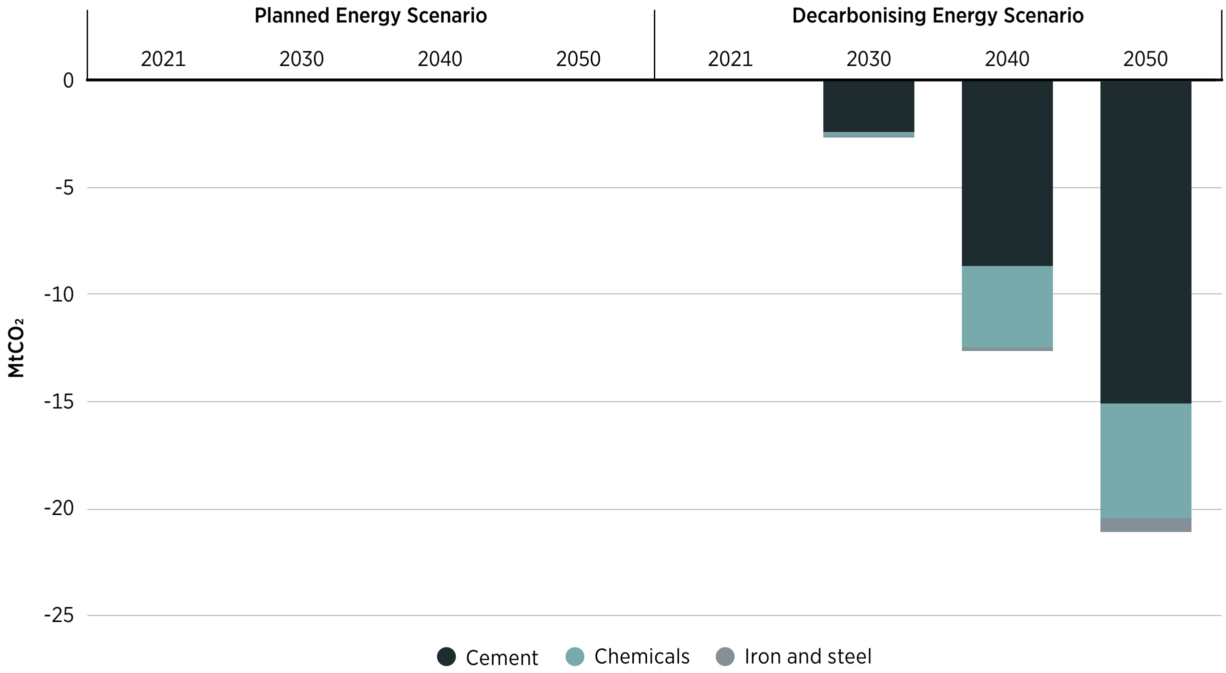


Note: $MtCO_2$ = million tonnes of carbon dioxide.

Driven by more optimisation of low carbon technologies, the DES sees industry emissions plunge leaving only about 3 $MtCO_2$ by 2050. Transition towards direct-reduced iron and scrap electric arc furnace methods are the key to decarbonising iron and steel production in the region, leaving the sector with only 0.2 $MtCO_2$ by 2050 while capturing about -0.7 $MtCO_2$. The role of CCS will be most apparent in the cement industry (see Figure 3.5), capturing -2.4 $MtCO_2$, -8.7 $MtCO_2$ and -15 $MtCO_2$ in the DES by 2030, 2040 and 2050, respectively. Using CCS causes cement industry emissions in the DES to grow only 8% over 2021, by 2030, far lower than in the PES, where they rise 38% over their 2021 value, to 16.7 $MtCO_2$. The transition towards alternative fuel, improving the ratio of clinker to cement and utilising CCS has the cement sector emitting about 0.5 $MtCO_2$ by 2050 in the DES.

The chemical industry is projected to capture about -5 $MtCO_2$ by 2050 in the DES, leaving the sector emitting about 0.3 $MtCO_2$. To ensure the accelerated implementation of CCS technologies, appropriate policy frameworks are paramount.

Figure 3.5 Industry: CO_2 emissions captured, by sub-sector



Note: $MtCO_2$ = million tonnes of carbon dioxide.

Key performance indicators for the region's industry are summarised in Table 3.1. Renewables' share in the sector grows significantly by 2050 both in the PES and DES, reaching 5% and 14% respectively. Including consumption of electricity from renewable sources, the share of direct and indirect renewables in 2050 is around four times the share of direct renewables in both scenarios, reaching 21% and 48% in the PES and DES respectively.

In the base year electricity accounts for about one-fifth of the sector's energy consumption. Accelerated electrification in the DES drives electricity consumption to about 31% of energy consumption by 2050, while the share of fossil fuels drops to one-quarter in the same year, from two-thirds in the base year. The role of hydrogen should have started to emerge in 2030, reaching 8.6 exajoule (EJ) by 2050 in the DES, consuming about 72 kilotonnes (kt) of hydrogen by 2050, mainly for the decarbonisation of iron and steel production. Considering also non-energy uses (*e.g.* fossil fuel as feedstock in chemicals and iron production), the sector's total energy consumption is projected to grow about 1.3-fold and 1.1-fold in the PES and DES, respectively, by 2050.

Table 3.1 Industry: Key performance indicators

	HISTORICAL	PLANNED ENERGY SCENARIO			DECARBONISING ENERGY SCENARIO		
	2021	2030	2040	2050	2030	2040	2050
KPI.02 RENEWABLES							
Share of renewables - direct use (%) in FEC	0%	4%	5%	5%	8%	11%	14%
Share of renewables - direct and indirect use (%) in FEC	5%	17%	18%	21%	23%	35%	48%
KPI.03 ENERGY INTENSITY							
Industry - final consuption (PJ)	1 167	976	1 264	1 538	918	1 124	1 299
KPI.04 ELECTRIFICATION OF END-USE SECTORS (DIRECT)							
Share of electricity in industry FC (%)	18%	19%	19%	19%	20%	25%	31%
Electricity consumption in industry (TWh)	59	52	67	80	51	78	111
KPI.05 CLEAN HYDROGEN AND DERIVATIVES							
Clean hydrogen consumption in industry (EJ)	0	0	0	0	0	3	9
Clean hydrogen consumption in industry (t)	-	-	-	-	2 224	24 105	72 011
KPI.06 CCS, BECCS AND OTHERS							
CCS ($MtCO_2$ captured/year)	0	0	0	0	-3	-13	-21
EMISSIONS							
CO_2 emissions with carbon capture and removal ($MtCO_2$/year)	59	37	45	52	29	18	3

Notes: BECCS = bioenergy with carbon capture and storage; CCS = carbon capture and storage; EaP= Eastern Partnership; EJ = exajoule; FC = final consumption; FEC = final energy consumption; KPI = key performance indicator; $MtCO_2$ = million tonnes of carbon dioxide; PJ = petajoule; TWh = terawatt hour; t = tonnes

3.3 KEY ACTIONS AND PRIORITIES IN INDUSTRY

Table 3.2 summarises the measures considered in the DES by sub-sector and measure type. These measures can serve as a reference for the efforts needed to reach the emissions reductions articulated in the DES.

Table 3.2 Industry: Measures considered in the Decarbonising Energy Scenario, by sub-sector

SUB-SECTOR	MEASURES
Iron and steel	• Shift primary production in the iron and steel industry in the region towards direct-reduced iron (DRI), using hydrogen DRI and natural gas DRI with carbon capture and storage (CCS) • Raise scrap steel production using electric arc furnaces to 65% of the region's steel production
Chemicals	• Move towards electrochemical and bio-based production of methanol, ethylene, chlorine and ammonia, with implementation of CCS
Cement	• Reduce ratio of clinker to cement to 0.7 • Implement 60% alternative fuel (30% biomass based) by 2030, and 90% alternative fuel (50% biomass based) by 2050
Other industries	• Phase out coal and oil products by 2050 • Cut natural gas use in half by 2050 • Electrify and optimise district heating • IIncrease the use of biofuel to compensate for the phasing down of fossil fuels

Notes: CCS = carbon capture and storage; DRI = direct-reduced iron.

Table 3.3 presents the measures and actions recommended for reaching the targets presented in Table 3.2 in the DES.

Table 3.3 Industry: Key actions and priorities in the Decarbonising Energy Scenario

OUTCOMES	MEASURES AND ACTIONS SUGGESTED
A more renewable and decarbonised industry sector	• Plan and accelerate the implementation of key infrastructure projects, *e.g.* for green hydrogen and carbon dioxide transport/storage, to support industrial decarbonisation • Accelerate development of hydrogen infrastructure such as electrolysers, hydrogen transport and storage infrastructure, and hydrogen hubs connecting industrial clusters in the region. • Develop carbon dioxide transport infrastructure and long-term storage sites to ramp up the implementation of carbon capture, utilisation and storage • Develop and implement incentive schemes *e.g.*: soft loans and/or tax relaxation for industry frontliners to implement low carbon technology, including bioenergy • Promote public-private partnerships to encourage research and development in clean and green technologies
Accelerated low carbon decarbonising technologies	• National governments shall prioritise research on and development of innovative low carbon industry technologies • Increase investment in research and development to accelerate the use of hydrogen and carbon capture technology • Encourage public-private partnerships to accelerate development of clean and green technologies
Collaboration among the countries to advance co-operation with other regions	• Strengthen the collaboration within the Eastern Partnership countries and with the European Union to accelerate the transfer of technology, knowledge and skill • Harmonise standards and certification to facilitate the creation of markets for green products
Digitalisation to aid in the sector's decarbonisation	• Accelerate industry digitalisation to facilitate the development of continuous measurement, reporting and verification schemes to monitor progress in decarbonisation • Encourage policy adjustments based on real-time data and feedback from industry players and help fine-tune regulatory measures and incentives

4

BUILDINGS

This chapter presents the main outcomes, findings and messages of the buildings sector analysis for the Eastern Partnership (EaP) countries. Key considerations addressed include:

1 What is the status of energy demand and decarbonisation in the region's buildings sector?

2 Are current plans, strategies and measures adequate to significantly reduce the sector's emissions by 2050?

3 What additional measures could be implemented to further decarbonise the sector?

4 Where should policy makers focus their attention?

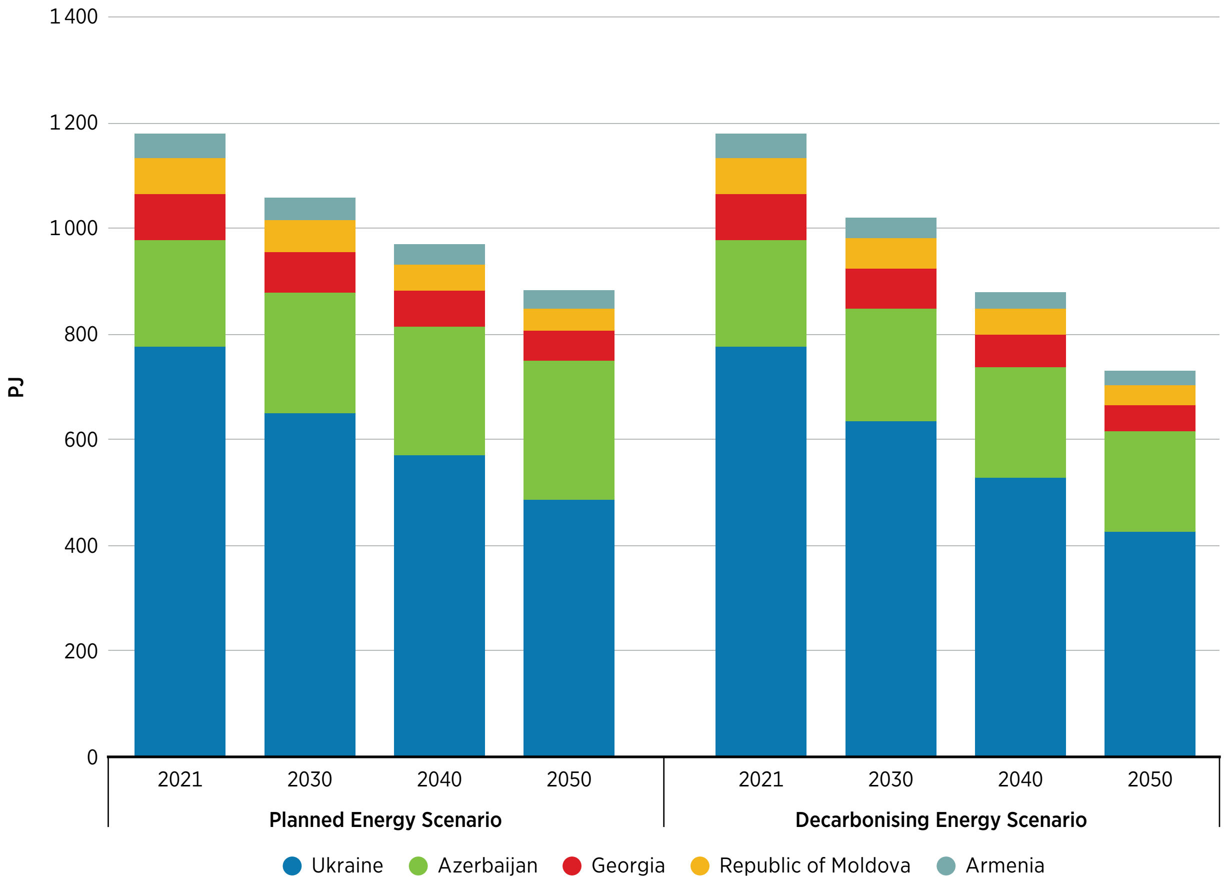
The analysis of the buildings sector comprises two sub-sectors: residential and commercial. Due to the nature of the model used for the analysis, public and government buildings were grouped within the commercial sub-sector.

4.1 REGIONAL CONTEXT

Buildings account for a substantial share of energy demand throughout the region. The residential sub-sector represented approximately 80% of the buildings sector's final energy consumption in 2021 and will continue to dominate by 2050 in both the Planned Energy Scenario (PES) and the Decarbonising Energy Scenario (DES). Most of the residential buildings in the EaP countries were built between 1960 and 1990, when building codes and standards were lower than today's in terms of energy efficiency. Additionally, many structures were not adequately maintained after the geographical and political changes that occurred in the region after December 1991. As a consequence, the residential sub-sector has great potential for reducing its energy demand and related greenhouse gas emissions in the run-up to 2050. The commercial sub-sector also offers great potential for decarbonisation through reductions in their energy consumption and related greenhouse gas emissions.

Energy consumption in the sector is dominated by Ukraine (66% share in 2021) followed by Azerbaijan (17% share in 2021) in both scenarios and over the entire study period (2021-2050), as seen in Figure 4.1. This dominance is due to Ukraine's considerably higher population and stock of buildings compared to the rest of the EaP countries. In 2050, Ukraine's share in the region's energy consumption in the buildings sector will be 55% in the PES and 58% in the DES.

Figure 4.1 Buildings: Final energy consumption, by country



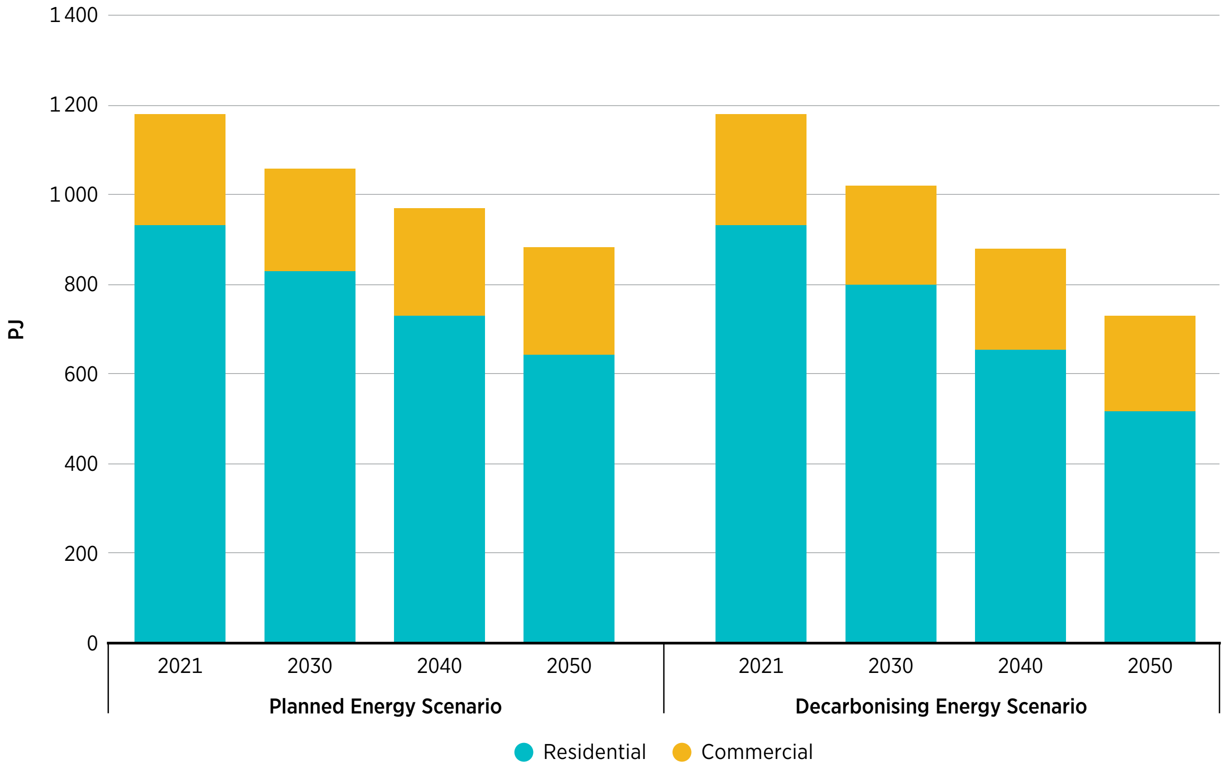
Note: PJ = petajoule.

4.2 OVERVIEW OF THE BUILDINGS SECTOR

Energy demand by sub-sector

Energy consumption in the sector is dominated by the residential sub-sector. As shown in Figure 4.2, residential buildings were responsible for almost 80% of the sector's energy consumption in 2021 and will continue to dominate demand by 2050 (73% in the PES and 71% in the DES). For the sector as a whole, both scenarios achieve important energy reductions over 2021, but the reduction is greater in the DES by 2050 (38%) than in the PES (25%) owing to a faster pace of renovation of the existing building stock and a higher rate of electrification of heating services.

Figure 4.2 Buildings: Final energy consumption, by sub-sector



Note: PJ = petajoule

Table 4.1 presents the energy reductions from 2021 for each scenario and sub-sector, and for the sector as a whole. The residential sub-sector achieves a larger reduction than the commercial sub-sector, even though both have a similar annual renovation rate in the scenarios (1% in the PES and 2% in the DES):

1. Energy demand in the residential sub-sector is dominated by natural gas (53% share in 2021). The main energy carrier in the commercial sub-sector is electricity, with a 51% share in 2021.
2. In both sub-sectors and in both scenarios, the share of natural gas in the energy mix decreases through 2050, while the share of electricity increases.
3. The electrification of heating services has a larger impact on demand in the residential sub-sector because it replaces natural gas–fuelled equipment with more efficient technologies.

By 2050, the residential sub-sector could achieve energy savings over 2021 of up to 44% (415 PJ) in the DES, but only 31% in the PES (293 PJ).

Table 4.1 Buildings: Energy savings by sub-sector compared to 2021

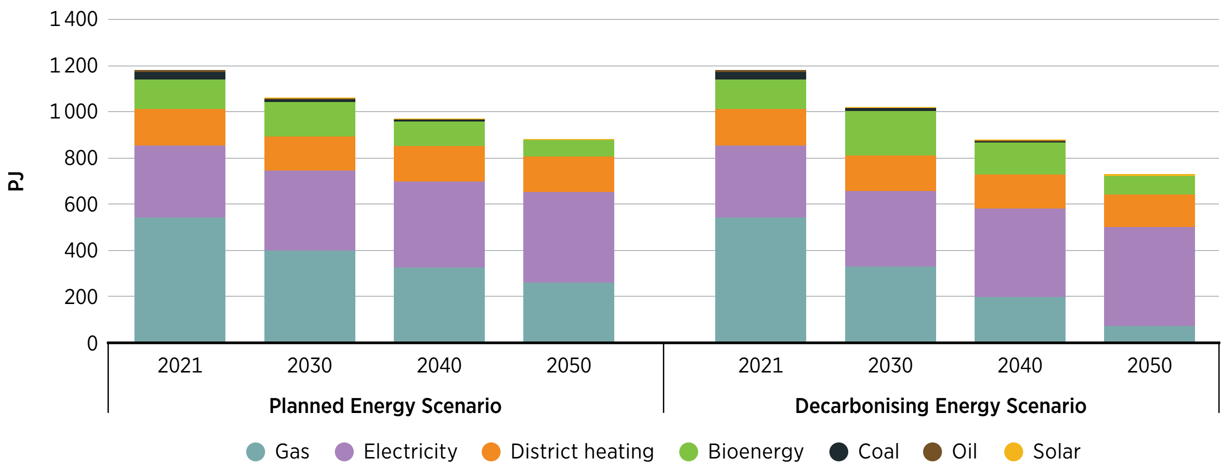
SCENARIO	YEAR	RESIDENTIAL	COMMERCIAL	SECTOR
Planned Energy Scenario	2030	-11%	-7%	-10%
	2040	-22%	-2%	-18%
	2050	-31%	-2%	-25%
Decarbonising Energy Scenario	2030	-14%	-9%	-13%
	2040	-30%	-8%	-25%
	2050	-44%	-13%	-38%

The role residential buildings hold in the decarbonisation of the sector becomes even more prominent when one considers the possibility of final consumers becoming "active customers" capable of producing their own green electricity and injecting the surplus into the grid. Final consumers could also organise "energy communities" capable of producing their own electricity while being entitled to own, establish, purchase or lease distribution networks. End consumers in the commercial sub-sector could also become active consumers and participate in energy communities. An adequate regulatory framework would be necessary for these proposals to be implemented; an example is the EU Directive on Common Rules for the Internal Market for Electricity (Directive (EU) 2019/944). Provisions for active consumers appear in Article 15 and for energy communities in Article 16 (European Commission, 2019).

Energy mix in the buildings sector

The energy demand of the sector is met through several energy carriers. As of 2021, natural gas dominated the energy mix with a 46% share, followed by electricity (26%). Figure 4.3 presents the energy mix in 2021 and its evolution for both scenarios. As can be seen, natural gas continues dominating the energy mix (although with a decreasing share) in both scenarios approaching 2050. Consumption of natural gas falls by 52% in the PES by 2050 from its 2021 level, while in the DES the drop is 86%. This difference translates into 189 PJ less gas required by 2050 in the DES. The reasons behind the difference are better energy efficiency in buildings (mainly through renovation of building envelopes) and electrification of heating services (space heating, water heating, cooking) in the run-up to 2050.

Figure 4.3 Buildings: Final energy consumption, by carrier

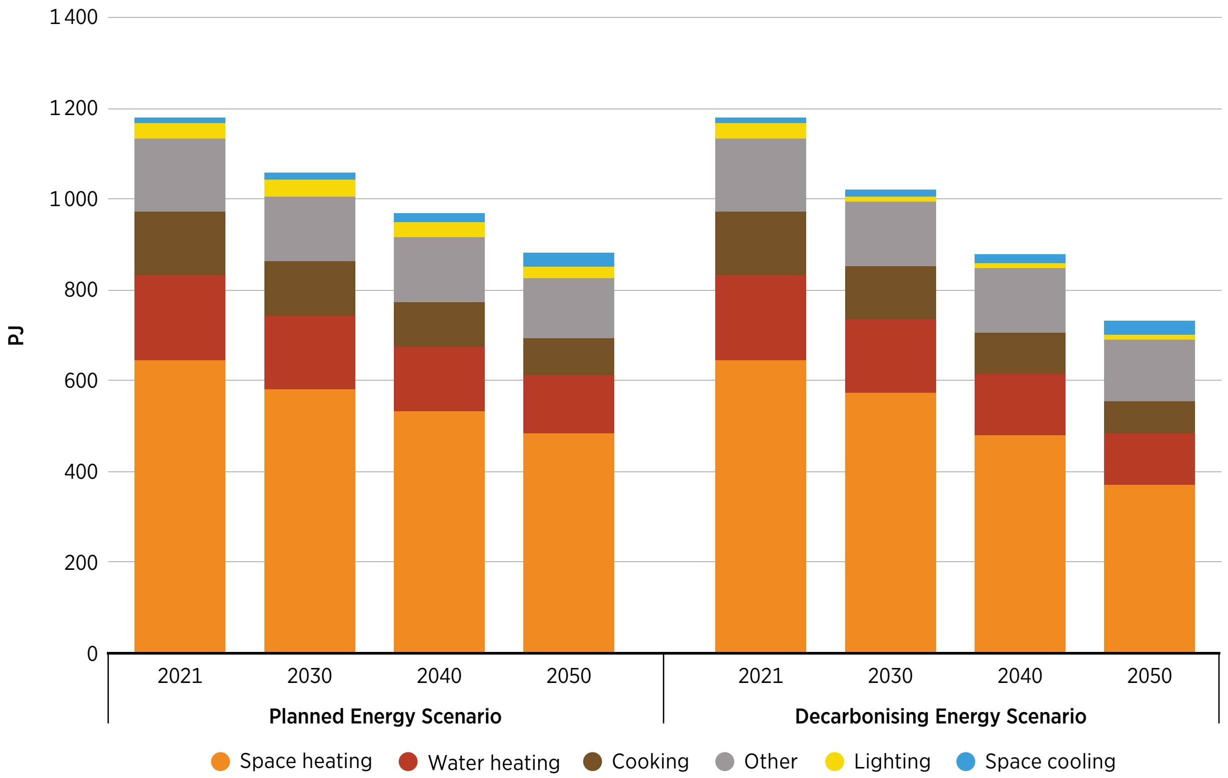


Note: PJ = petajoule.

Heating services

Heating services dominate energy consumption in the buildings sector, as shown in Figure 4.4, with space heating the largest segment (55%) in 2021, followed by water heating (16%) and cooking (12%). The decarbonisation potential is high owing to the presence of natural gas, coal and oil in the mix of energy carriers used to meet demand.

Figure 4.4 Buildings: Final energy consumption, by service



Note: PJ = petajoule.

The energy consumption of heating services declines over time, chiefly as a result of electrification and better thermal insulation in buildings, especially in the residential sub-sector, which represents the largest consumer in both sub-sectors. Energy savings relative to 2021, by heating service, are reviewed in Table 4.2.

Table 4.2 Buildings: Energy savings for heating services, with reference to base year 2021

SCENARIO	YEAR	SPACE HEATING	WATER HEATING	COOKING
Planned Energy Scenario	2030	-10%	-13%	-14%
	2040	-17%	-24%	-30%
	2050	-25%	-31%	-41%
Decarbonising Energy Scenario	2030	-11%	-14%	-15%
	2040	-25%	-29%	-34%
	2050	-43%	-39%	-48%

The electrification of heating services will play an important role in the sector's future energy demand and emissions. Figure 4.5 shows the penetration of heat pumps in the EaP countries from 2030 to 2050 in both scenarios. Figure 4.6 presents the related electricity consumption and its change over time, also for both scenarios. As shown in the two figures, the increase in electricity consumption from the use of heat pumps is linked to their higher penetration in the sector, mainly for space heating and, to a lesser extent, for water heating. In this regard, Ukraine holds the largest share in penetration and energy consumption in both scenarios over the period 2030-2050, followed by Azerbaijan. This is due to Ukraine's larger population and stock of buildings (dominated by the residential sub-sector) compared to the rest of the EaP countries.

Figure 4.5 Buildings: Stock of heat pumps 2030-2050

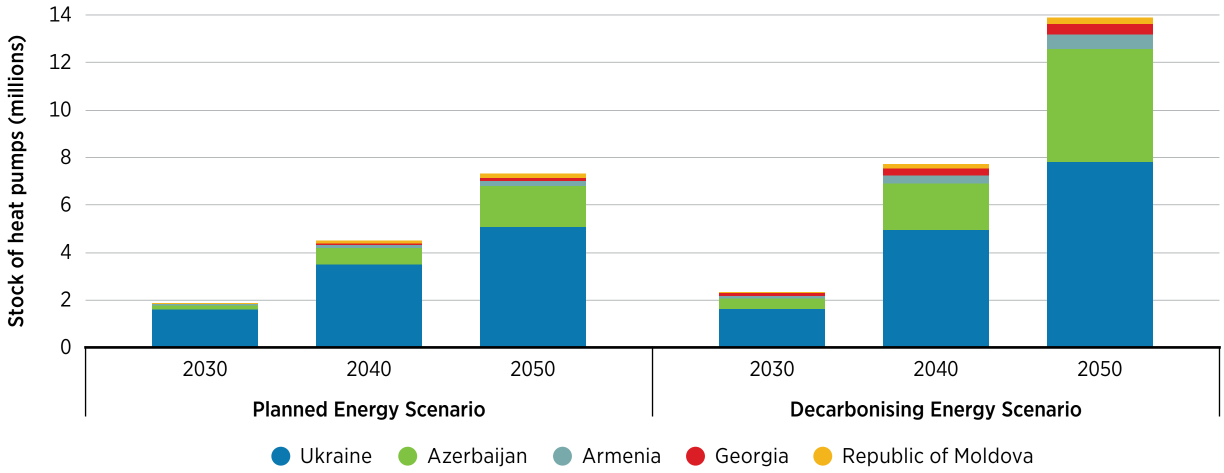
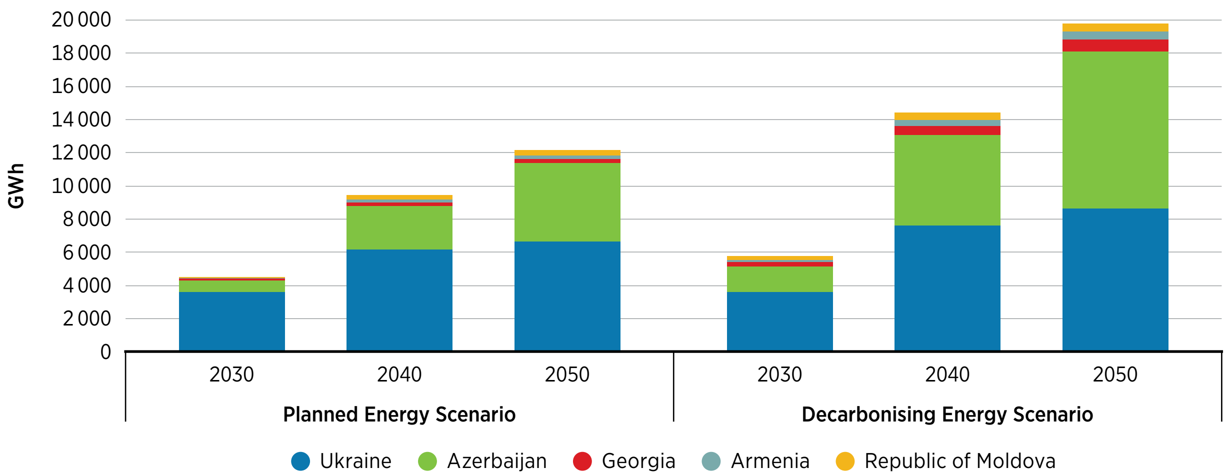


Figure 4.6 Buildings: Electricity consumed by heat pumps, 2030-2050



Note: GWh = gigawatt hour.

As shown in Figure 4.6, electricity consumption from heat pumps could rise by 2030 to 4 458 gigawatt hours (GWh) in the PES and 5 742 GWh in the DES. By 2050, consumption could increase further to 12 202 GWh in the PES and 19 799 GWh in the DES. The difference between scenarios is 29% in 2030 and 62% in 2050, a disparity linked to the higher electrification rate of space heating in the DES in both sub-sectors. The increasing electricity consumption from heat pumps in both scenarios needs to be considered by the power sector system planners to ensure that the transmission and distribution capacity of the power lines in each country will be able to handle the increase. Electricity consumption by heat pumps is expected to represent 17% of the sector's total electricity demand in the EaP countries by 2050 in the DES, but only 11% in the PES. The disparity represents an additional 7 597 GWh that would need to be considered in power system expansion plans.

The energy landscape of the buildings sector through 2050

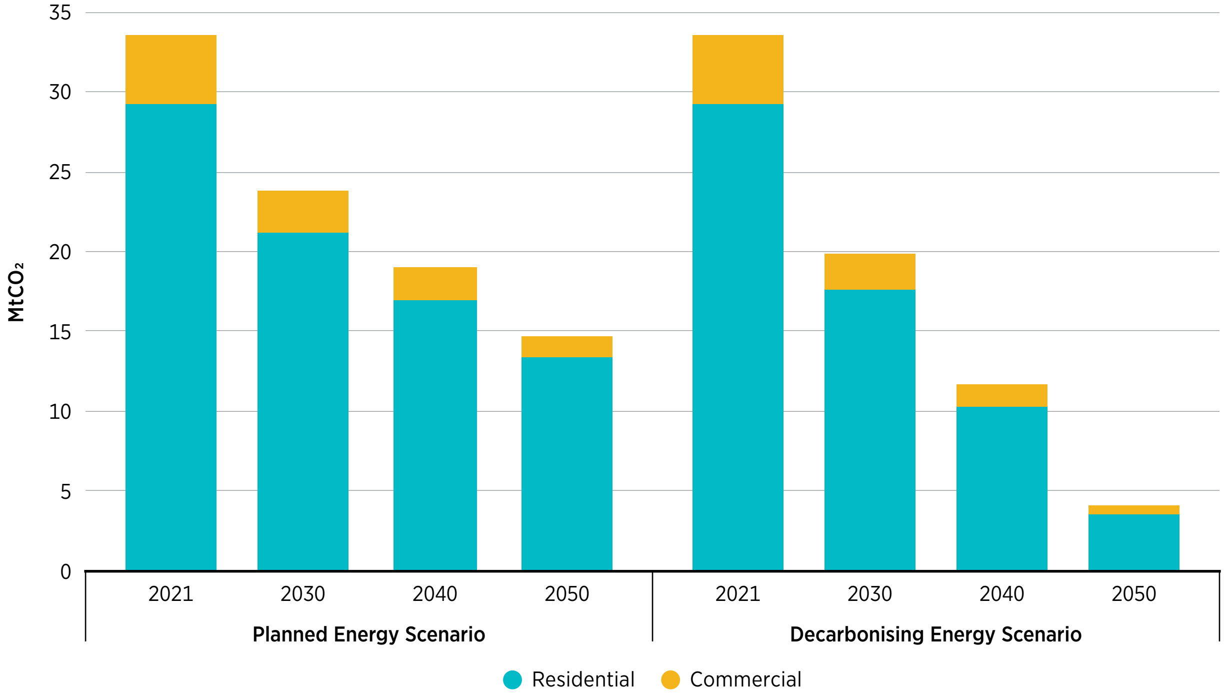
Table 4.3 summarises the energy landscape of the buildings sector for both scenarios between 2030 and 2050. As is evident, the DES achieves greater energy efficiency in the run-up to 2050 by consuming 151 PJ less than the PES. The total share of renewables in the energy mix for buildings is also greater in the DES, rising from 16% in 2021 to 53% in 2050, compared to only 28% in the PES. The impact on the sector's CO_2 emissions is also remarkable, moving from 34 $MtCO_2$ in 2021 to 15 $MtCO_2$ by 2050 in the PES and to 4 $MtCO_2$ in the DES. The residential sub-sector remains the largest emitter over the time period covered by the study, as presented in Figure 4.7. The reasons behind the better outcomes in the DES can be summarised as (1) more-extensive building renovations, (2) greater electrification of heating services, and (3) use of biomethane (18% mix) in the natural gas grid across all countries.

Table 4.3 Buildings: Key performance indicators for the sector

	HISTORICAL	PLANNED ENERGY SCENARIO			DECARBONISING ENERGY SCENARIO		
	2021	2030	2040	2050	2030	2040	2050
KPI.02 RENEWABLES							
Share of direct renewables (%)	11%	14%	11%	9%	19%	16%	12%
Share of direct and indirect renewables (%)	16%	26%	24%	28%	32%	43%	53%
District heat consumption (PJ)	158	150	149	149	152	148	143
KPI.03 ENERGY CONSERVATION AND EFFICIENCY							
Total final consumption (PJ)	1 179	1 059	970	882	1 021	881	731
KPI.04 ELECTRIFICATION OF END-USE SECTORS (DIRECT)							
Electricity share (%)	26%	32%	39%	45%	32%	44%	58%
KPI.05 CLEAN HYDROGEN AND DERIVATIVES							
Clean hydrogen consumption (PJ)	0	0	0	0	0	0	0
EMISSIONS							
CO_2 emissions with carbon capture and removal ($MtCO_2$/yr)	34	24	19	15	20	12	4

Notes: $MtCO_2$/year = million tonnes of carbon dioxide per year; PJ = petajoule

Figure 4.7 Buildings: CO_2 emissions, by sub-sector



Note: $MtCO_2$ = million tonnes of carbon dioxide.

4.3 KEY ACTIONS AND PRIORITIES IN BUILDINGS

Table 4.4 summarises the measures considered in the DES by sub-sector. These measures can serve as a reference for the efforts needed to reach the emissions reductions specified in the DES.

Table 4.4 Buildings: Measures considered in the Decarbonising Energy Scenario, by sub-sector

SUBSECTOR	MEASURES
Residential	**District heating** • The share of district heating in the technology mix for the heating services is kept constant in all countries possessing heating grids. This is done to better utilise the existing infrastructure and, whenever possible, produce heat from renewable sources
	Electrification of heating services • The stock of installed heat pumps increases at an average annual rate of 9% between 2030 and 2050 • The electricity consumed by heat pumps reaches 17 767 GWh by 2050, representing 22% of the total electricity demand of the residential sub-sector
	Energy efficiency • Buildings are renovated at the rate of 2% per year • The residential sub-sector realises a 46% savings on space heating by 2050 over 2021, a gain of 259 PJ • The residential sub-sector as whole achieves 44% savings by 2050 over 2021, a gain of 415 PJ
	Biomethane blending • A biomethane blending share of 18% is assumed for all countries by 2030. This blend increases by 10% in each decade relative to the prior one, reaching 20% by 2040 and 22% by 2050

Commercial (including public buildings)	**District heating** • The share of district heating in the technology mix for heating services is held constant in all countries possessing heating grids
	Electrification of heating services • Heat pumps are deployed at an average annual rate of 8% between 2030 and 2050 • Electricity consumed by heat pumps reaches 2 032 GWh by 2050, representing 5% of the commercial sub-sector's total electricity demand
	Energy efficiency • Buildings are renovated at the rate of 2% per year • The commercial sub-sector realises a 20% savings on space heating by 2050 over 2021, a gain of 17 PJ • The commercial sub-sector as a whole achieves 13% savings by 2050 over 2021, a gain of 32 PJ
	Biomethane blending • A biomethane blending share of 18% is assumed for all countries by 2030. This blend increases by 10% in each decade relative to the prior one, reaching 20% by 2040 and 22% by 2050

Notes: GWh = gigawatt hour; PJ = petajoule.

Table 4.5 presents the measures and actions recommended for reaching the targets articulated in the DES.

Table 4.5 Buildings: Key actions and priorities for the decarbonising energy scenario

OUTCOMES	MEASURES AND ACTIONS SUGGESTED
Reduction of energy demand by at least 13% by 2030 and 38% by 2050 relative to 2021	• Raise renovation rates to at least 2% per year to cut energy demand for space heating • Modernisation and adoption of building codes and standards at the national level to ensure uniform energy performance in new residential buildings • Develop training programmes for a skilled workforce to carry out the renovation works needed. • Develop a local and/or regional supply chain for the renovation of buildings
Electrification of the heating services	• Deploy heat pumps at an average annual rate of 9% between 2030 and 2050 for space heating, and to a lesser extent, for water heating • Deploy electric stoves for cooking at an average annual rate of 4% each year to 2050
Reduction of natural gas consumption by 39% in 2030 and 86% by 2050 relative to 2021	• Electrify heating services (space heating, water heating, cooking) • Scale up biomethane production and grid injection: an 18% biomethane blend in the natural gas grid by 2030, rising to 20% by 2040 and 22% by 2050 • Increase buildings' energy efficiency (especially for space heating) to cut energy demand by at least 13% of the 2021 level by 2030 and 40% by 2050 • Preserve, modernise and, where possible, expand district heating networks

5

POWER SECTOR, AND GREEN HYDROGEN AND DERIVATIVES

The Eastern Partnership (EaP) region is entering a decisive phase in its energy transition. Armenia, Azerbaijan, Georgia, the Republic of Moldova and Ukraine all face a complex set of geopolitical, economic, and environmental challenges, including aging power infrastructure, dependency on imported fossil fuels, and growing exposure to the risks of climate change and global market realignments. At the same time, the region is endowed with substantial renewable energy resources and could benefit from deepening co-operation with the European Union and international partners. With varying levels of market readiness, regulatory capacity, and investment climates, the EaP countries are increasingly aligning their national strategies with regional and global decarbonisation objectives.

Two scenarios frame the analysis in this report: a Planned Energy Scenario (PES), reflecting current national plans and policies; and a Decarbonising Energy Scenario (DES), an alternative pathway aligned with the 1.5°C global warming goal of the Paris Agreement. The analysis of the power sector presented here provides an integrated perspective on how regional electricity systems might evolve under each scenario, taking into account technology costs, infrastructure needs, and institutional capacity.

Guiding questions for the analysis are as follows.

- What are the implications of current national plans (PES) versus more ambitious, co-ordinated action (DES) for the region's power sector and a more electrified energy system?
- How can the region's renewable energy potential be effectively harnessed to meet future electricity demand?
- What regional reforms and investments are needed to enable flexibility, inter-connection and large-scale renewable integration?
- What is the role of green hydrogen in decarbonisation and in supporting low-carbon exports?

5.1 OVERVIEW OF DEMAND GROWTH

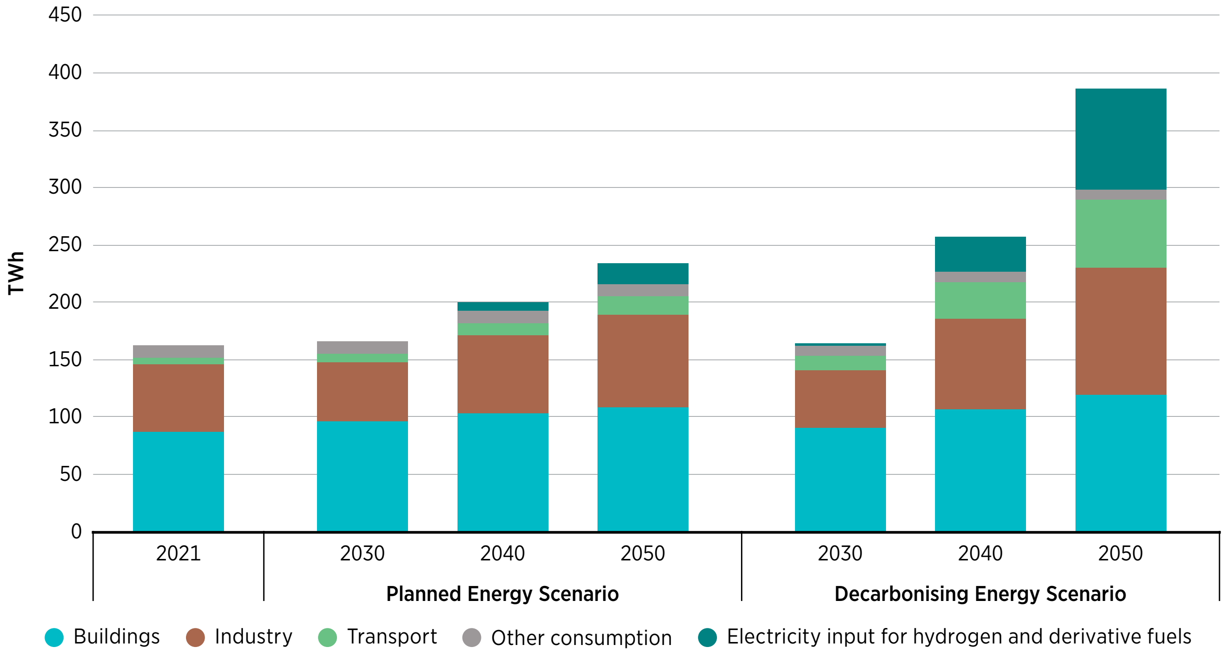
Electrification is a key part of the energy transition, and demand trajectories across the EaP region reflect both structural changes in end-use sectors and differing levels of policy ambition.

Electricity demand in the region (which differs from electricity generation because it excludes system losses, own consumption by generators and trade activity in electricity) is projected to increase modestly under the PES, reaching approximately 234 TWh by 2050, compared to 162 TWh in 2021, as shown in Figure 5.1. Under the DES, demand rises much more sharply, almost doubling to 377 TWh by 2050, driven by deep electrification of end-use sectors and the emergence of electricity-based hydrogen production.

- **Buildings.** Electricity demand in buildings continues a steady upward trend in both scenarios, with moderate growth owing to rising appliance use, urbanisation, and electric heating and cooling. However, demand rises faster in the DES due to deeper electrification of heating systems (*e.g.* heat pumps) and improved building efficiency.
- **Industry.** Under the PES, industrial electricity demand remains relatively flat through 2030, then grows moderately, reflecting structural shifts and output growth. In the DES, more aggressive electrification of process heat, accompanied by feedstock switching drives significantly higher demand, reaching 111 TWh by 2050.
- **Transport.** The most transformative difference between the PES and DES appears in the transport sector. In the DES, the widespread adoption of electric vehicles and rail electrification causes electricity demand to reach 59 TWh by 2050, nearly four times the PES level, which assumes slower uptake of e-mobility solutions.
- **Hydrogen and synthetic fuels.** This category is negligible in 2021 and marginal in the PES, reflecting minimal hydrogen deployment. In contrast, the DES foresees rapid scaling, with 79 TWh of electricity demand by 2050 for the production of green hydrogen and synthetic fuels. This reflects policy ambition to decarbonise hard-to-abate sectors and produce green ammonia and methanol for export which would align with the Carbon Border Adjustment Mechanism requirements in EU trade.

The difference between the PES and DES highlights the importance of long-term system planning. Under the PES, supply-side investments focused on incremental growth in line with these demand projections can be more moderate. Under the DES, the region must prepare for a more than doubling of electricity demand (see Figure 5.1), requiring major capacity additions, grid reinforcement, flexibility measures, and storage deployment. The power system will also need to evolve from today's relatively static demand profile towards a dynamic, demand-responsive, and low-carbon backbone that enables deep decarbonisation across all sectors. Anticipating this growth, and planning infrastructure, investment, and institutional frameworks accordingly, will be essential to a successful and secure energy transition.

Figure 5.1 Electricity consumption, by end-use sector and for hydrogen production, 2021-2050



Note: TWh = terawatt hour.

The power sector of the EaP region is set to evolve significantly, driven by increasing ambitions for electrification and integration of renewable energy. The key performance indicators for the EaP energy transition, as shown in Table 5.1, illustrate a transformative pathway under both the PES and the DES, charting a growingly renewable and low-carbon pathway.

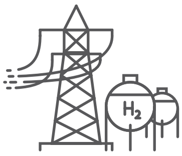
Total renewable power generation capacity is projected to rise from 23 GW in 2021 to 60 GW under the PES and 142 GW under the DES by 2050. By then, renewables will make up 64% and 81% of total installed capacity in the PES and DES, respectively. The expansion is dominated by variable renewables such as solar and wind. Solar power capacity grows nearly seven-fold, reaching 55 GW under the DES, while wind energy surges from just 2 GW in 2021 to 64 GW by 2050.

Electricity generation in the region is expected to more than double by 2050, from around 200 TWh in 2021 to 478 TWh under the DES, in response to the rapid electrification of end-use sectors. Electrification of transport, in particular, sees a substantial increase by 2050, from a modest 3% in 2021 to 48% under the DES. Similarly, industry and buildings reach electrification rates of 39% and 58%, respectively, under the DES.

The production of green hydrogen, which begins at near-zero levels, rises significantly to 1.7 Mt annually under the DES by 2050. This increase reflects its important role in decarbonising hard-to-abate sectors and providing seasonal storage. Battery storage capacity also scales up, from no significant deployment in 2021 to 12.6 GW by 2050 under the DES, supporting the integration of variable renewables and enhancing system flexibility.

These high-level indicators highlight the scale of transformation needed across the energy system in the EaP region. Achieving such goals will require robust policy frameworks, investments in grid infrastructure and storage, and strong regional co-operation. Together, these efforts can help the EaP ensure a clean, resilient, and future-ready power sector.

Table 5.1 Key performance indicators for the energy transition in the power sector of the Eastern Partnership countries: Tracking progress towards 2050



	HISTORICAL	PLANNED ENERGY SCENARIO			DECARBONISING ENERGY SCENARIO		
	2021	2030	2040	2050	2030	2040	2050
KPI.01 RENEWABLES (POWER)							
Total renewable capacity (GW)	23	32	41	60	46	91	142
Renewables' share in capacity (%)	30	48	56	64	59	74	81
Share of variable renewables in capacity (%)	13	25	32	45	37	57	68
Renewables' share in generation (%)	17	35	34	44	41	61	69
Capacity by technology – solar (GW)	8	12	14	23	19	34	55
Capacity by technology – wind (GW)	2	5	9	19	9	36	64
Capacity by technology – hydro (GW)	12	14	15	15	15	18	18
Total annual electricity generation (TWh)	199	191	272	308	223	325	478
Industry's electricity share in FEC (%)	22	24	24	24	25	31	39
Building's electricity share in FEC (%)	26	32	39	45	32	44	58
Transport's electricity share in FEC (%)	3	4	6	7	8	22	48
Battery storage capacity (GW)	0	1.5	3	4.6	3	6.1	12.6
KPI.05 CLEAN HYDROGEN AND DERIVATIVES							
Annual green hydrogen production (Mt)	0	0.2	0.3	0.5	0.3	1	2.2

Notes: GW = gigawatt; Mt = million tonnes; TWh = terawatt hour; FEC = Final Energy Consumption.

5.2 RENEWABLE ENERGY RESOURCE POTENTIAL IN THE EAP REGION

The EaP region holds significant and varied renewable energy potential across countries, offering a strong basis for clean energy development. Ukraine possesses extensive onshore wind and solar resources, particularly in its southern and eastern plains. The Republic of Moldova also has strong wind and solar potential relative to its land area. Georgia benefits from abundant hydropower capacity in its mountainous areas and wind corridors, while Armenia and Azerbaijan are well-positioned for solar photovoltaic (PV), with high irradiation levels and available land. Offshore wind presents a major long-term opportunity, particularly in the Black Sea and Caspian Sea.

The diversity of resource endowments across the region presents a clear opportunity for regional complementarity, as illustrated in Table 5.2. Countries with high hydropower potential, such as Georgia, could provide balancing and flexibility services to support the integration of variable wind and solar from other parts of the region. A co-ordinated approach to grid development, cross-border trade, and investment planning can help maximise the region's overall renewable potential while enhancing energy security and resilience.

Table 5.2 Estimated technical potential for renewable power resources

		Armenia	Azerbaijan	Georgia	Republic of Moldova	Ukraine
GW	Onshore wind	0.5	15	5.4	21	188
	Offshore wind	n.a.	157	n.a.	n.a.	251
	Solar photovoltaic	40	115	87	4.6	57
	Hydropower	1.4	1.7	15	0.8	7

Notes: These potentials rely on a range of documents and assessments (CEER, 2022; DIW Econ GmbH, 2024; Doronina *et al.*, 2024, 2025; Energy Community, 2024b; German Economic Team, 2024; IRENA, 2020, 2025c, 2025d; World Bank, 2020b, 2022).
GW = gigawatt.

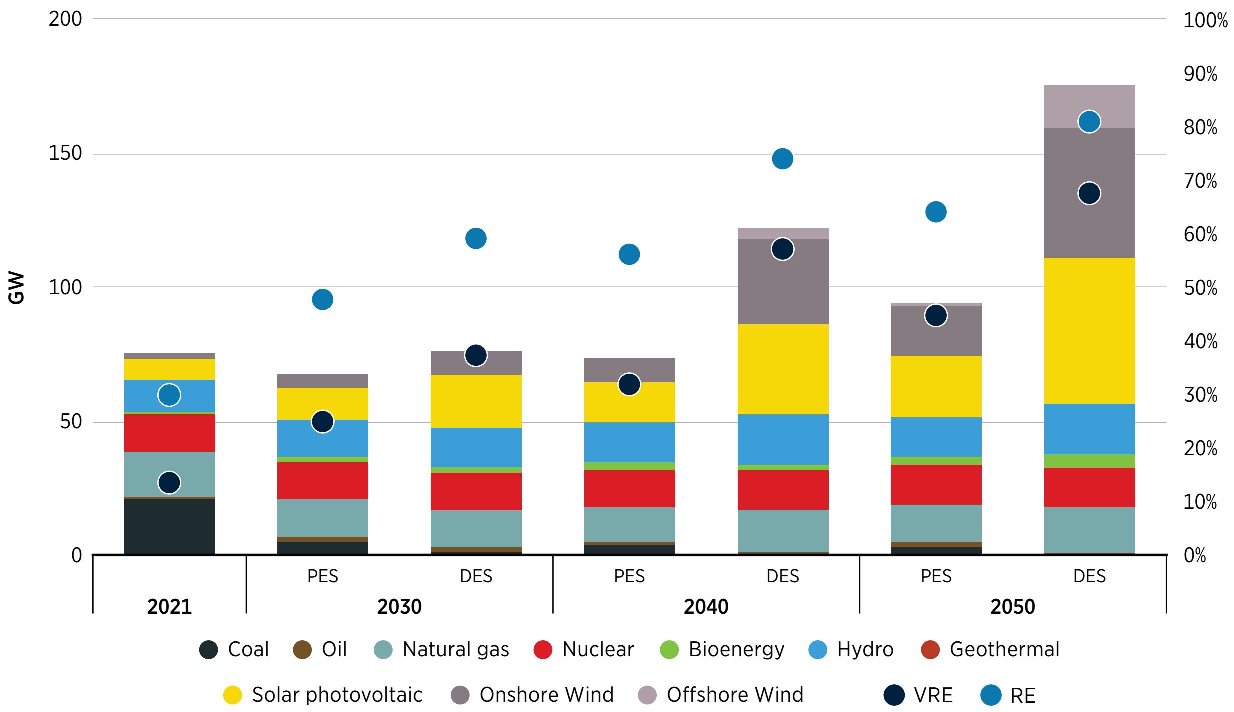
The growing electricity demand outlined in the previous section demonstrates the importance of harnessing the region's diverse renewable resources. Rising electricity use, particularly for transport, industry, and green hydrogen will require not only greater renewable capacity but also strategic co-ordination. The complementary nature of resources across countries offers an opportunity: flexible hydropower and large-scale wind and solar can together support a balanced, resilient and increasingly integrated regional power system across the EaP.

5.3 EVOLUTION OF CAPACITY AND POWER GENERATION FOR THE REGIONAL POWER SECTOR

Power generation capacity

The international distribution of renewable potential and the evolution of electricity demand will be key in shaping the expansion pathways of the power sector, as will enabling measures to deliver both scenarios. The installed capacity of power generation technologies for both the PES and DES is shown for key milestone years in Figure 5.2. Under an ambitious decarbonisation pathway, the DES, installed capacity could more than double, driven by electrification, rapid deployment of renewables, and the phasing out of coal. In contrast, the PES reflects a slower, more incremental (though still significant) shift.

Figure 5.2 Installed power generation capacity by technology and scenario



Notes: DES = Decarbonising Energy Scenario; GW= gigawatt; PES = Planned Energy Scenario; VRE = variable renewable energy.

In 2021, total installed capacity was about 76 GW, and was largely dependent on coal, gas, and aging hydro and nuclear power plants. Coal capacity is almost entirely located in Ukraine, while nuclear is concentrated in Ukraine (13.8 GW) and Armenia (0.4 GW). Natural gas capacity is more evenly distributed, with Azerbaijan, Ukraine, and Armenia holding the largest shares. By 2050, this rises to nearly 176 GW under DES, but only reaches 94 GW in the PES. This growth reflects both rising electricity demand and the lower capacity factors of renewables.

Fossil fuel based power capacity declines in both scenarios. Coal falls from 21 GW in 2021 to 4 GW in the PES by 2040 and 2050 and is fully phased out by 2040 in the DES. Gas remains present but shifts to more flexible, peaking roles. Azerbaijan and Ukraine continue to operate the bulk of regional gas capacity, while Armenia, Georgia, and the Republic of Moldova maintain smaller but steady levels. Oil remains in the system but its use is limited to a few instances per year.

Renewables lead the expansion in both scenarios and make up the bulk of capacity additions. Solar PV grows from 8 GW in 2021 to 55 GW in the DES by 2050; Ukraine leads (20 GW), followed by Azerbaijan (15 GW) and Armenia (6 GW), with smaller but notable growth in Georgia and the Republic of Moldova. Onshore wind rises from 2 GW to 48 GW, again driven by Ukraine (33 GW), with strong contributions from Georgia (9 GW) and Azerbaijan (4 GW). Offshore wind rises to 16GW by 2050 from very modest levels, which is concentrated in Azerbaijan (11 GW) and Ukraine (5 GW), enabled by access to the Caspian and Black Seas, respectively.

Together, variable renewables reach nearly 70% of total capacity in DES, and 45% even in PES by 2050. Hydropower grows modestly to 18 GW in DES, maintaining its role in balancing over the same period, while bioenergy expands to between 3 GW and 5 GW depending on scenario. Nuclear stays stable at 15 GW in both scenarios, its use remaining split between Ukraine and Armenia, with no new countries developing nuclear capacity.

The DES also introduces offshore wind, which reaches 16 GW by 2050. Though smaller in scale, it offers strategic value for diversification of power sources, grid balancing and green hydrogen production.

By 2050, over 80% of the DES capacity is renewable, up from 30% in 2021, demanding parallel investment in smart grids, storage, and digital infrastructure to manage variability and ensure effective system operation. This shift is uneven across countries. Ukraine sees the most diversified mix and largest absolute growth, while Azerbaijan leads in offshore wind and solar, and Georgia owes much of its renewable expansion to hydro and onshore wind potential. Smaller countries like Armenia and the Republic of Moldova also make meaningful relative gains across various technologies, most notably onshore wind and solar.

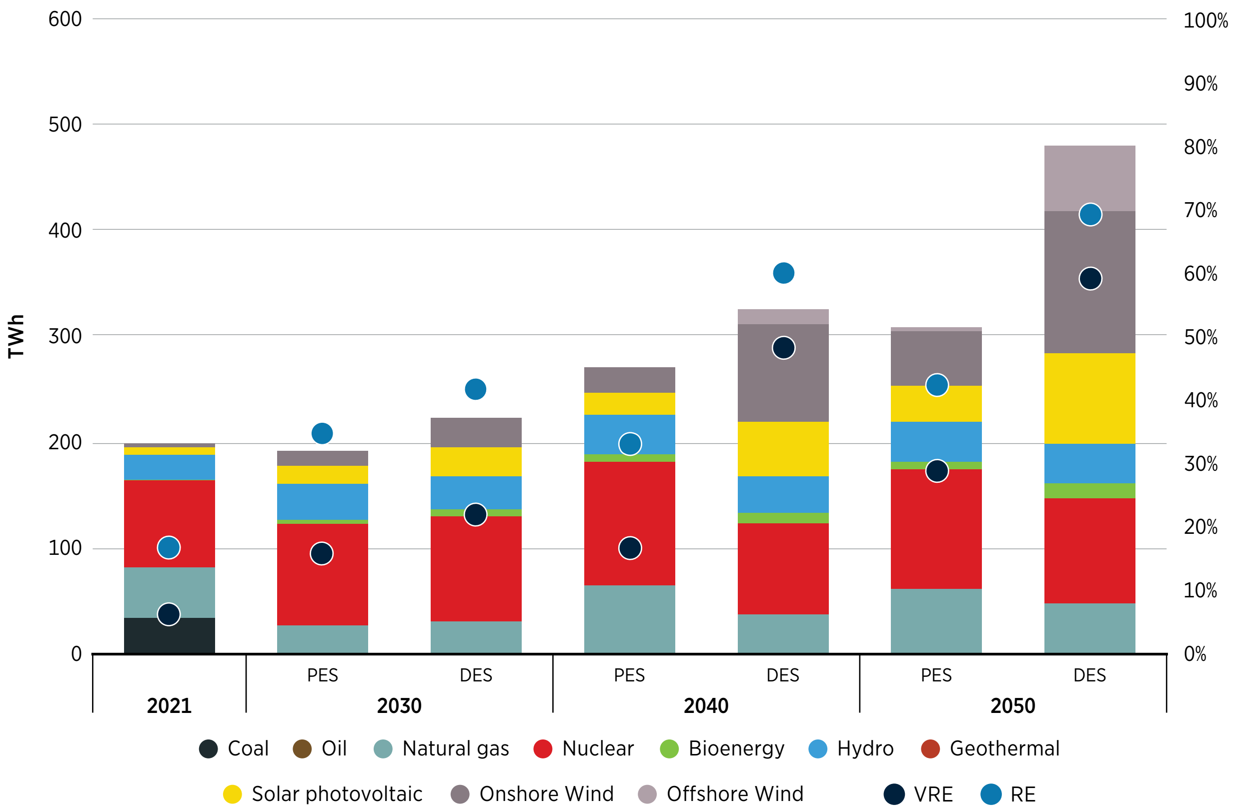
PES, by contrast, reflects limited grid upgrades, slower renewable uptake, and continued fossil reliance, leading to higher long-term costs and divergence from EU climate policies in the longer term, including the Carbon Border Adjustment Mechanism.

In essence, the PES builds upon the status quo but does still entail incremental increases in renewable expansion, while the DES charts a bold, sustainable energy future. Achieving the DES will require strong policies, investment, and regional co-ordination, but the country-level trends show that each EaP country can play a distinct role in the transition. It demonstrates that a cleaner, more resilient power system in the EaP region is within reach.

Power generation

While the capacity expansion of power generation capacity lays the foundation, electricity generation reveals how power systems function and evolve across the region. In the EaP region, power generation characteristics diverge significantly between the PES and the DES, differing in mix, system behaviour, and the role of renewables, dispatchable assets, and fossil fuels. The evolution of power generation in both scenarios can be seen in Figure 5.3.

Figure 5.3 Power generation by technology and scenario



Notes: DES = Decarbonising Energy Scenario; PES = Planned Energy Scenario; RE = renewable energy; TWh = terawatt hour; VRE = variable renewable energy.

In 2021, the region generated around 200 TWh of electricity, mostly from coal, gas, and nuclear. Coal alone provided nearly 40 TWh. Renewables accounted for around 17%, with variable renewables like wind and solar contributing just 5%. Ukraine accounted for most of the total generation, particularly from coal and nuclear, producing nearly all of the region's coal-based electricity and the vast majority of nuclear output in both the PES and DES. Azerbaijan and Armenia also contributed significantly through gas and nuclear, respectively, while Georgia relied largely on hydropower. The Republic of Moldova's generation was limited and highly dependent on imports.

By 2050 under the DES, generation needs more than double to 478 TWh. Coal is phased out by 2040; oil remains negligible. Natural gas shifts to playing a more flexible backup role, amounting to 47 TWh in the DES by 2050, which is lower than the 56 TWh in the PES. Despite a modest expansion of capacity out to 2050 in both scenarios, nuclear power generation grows from 80 TWh in 2021 to 98 TWh in the DES, with the PES seeing greater levels than the DES owing to nuclear's limited operational flexibility. In the PES, nuclear power generation is 111 TWh in 2050. This reflects high nuclear utilisation in Ukraine under the PES, while Armenia's remains stable across both scenarios.

Renewables drive a profound system transformation in the DES. Wind and solar jump from 10 TWh in 2021 to around 277 TWh by 2050. Solar PV grows ten-fold to 84 TWh; onshore wind rises to 134 TWh. Offshore wind, while largely absent today, reaches 60 TWh by 2050. Ukraine accounts for nearly half of total variable renewable energy (VRE) generation in the DES, driven by its large-scale wind and solar deployment. Azerbaijan becomes a key offshore wind producer, generating around 40 TWh by 2050, thanks to strong potential in the Caspian Sea. Georgia and Armenia also see notable increases in onshore wind and solar output, respectively, given favourable local conditions. The Republic of Moldova sees smaller but important VRE contributions relative to its system size. Under the DES, VRE makes up nearly 60% of total generation in 2050, up from 5% in 2021. The PES also sees growth, but only to 29%.

Hydropower, crucial for balancing and system inertia in critical periods, increases from 23 TWh in 2021 to 35 TWh in the PES and 39 TWh in the DES by 2050. The growth is concentrated in Georgia and Ukraine, both of which expand or repurpose existing hydro resources to support VRE integration. Armenia and Azerbaijan maintain steady output, while the Republic of Moldova does not contribute significantly to hydro generation. Bioenergy rises to 15 TWh under the DES, mainly through biomass fuelled combined heat and power, and district heating.

By 2050, renewables supply 69% of electricity generation under DES, with fossil fuels and nuclear at 21%. The PES lags with a 44% renewables share and greater gas reliance. The DES sharply reduces carbon intensity, approaching near zero by 2050 and so aligning with EU climate targets and supporting emerging clean exports like green hydrogen and electrified industrial goods. Ukraine's transformation is particularly important here, as it shifts from a coal- and nuclear-heavy system in 2021 to a diversified renewables mix, including significant offshore wind. Azerbaijan plays a dual role, both advancing solar and offshore wind domestically and maintaining gas as a strategic export. Georgia builds a clean system anchored in hydro and wind, while Armenia pursues a mixed path with renewables, nuclear and flexible gas.

This shift requires major investments in grids, flexibility and institutions. But the benefits are clear: lower emissions, better air quality, renewable job growth, energy security, and long-term savings. Each country's pathway is distinct, but all contribute to the region's overall decarbonisation and integration with European energy and climate objectives.

5.4 GREEN HYDROGEN AND ITS DERIVATIVES

Green hydrogen is emerging as a strategic priority in the EaP, especially for Azerbaijan and Ukraine, both of which have outlined plans to develop a hydrogen economy (Government of Ukraine, 2024a; Republic of Azerbaijan, 2024). While starting from a low base, hydrogen consumption and production are expected to increase significantly over the coming decades. In some countries, existing hydrogen use, primarily grey hydrogen, offers an opportunity for decarbonisation, particularly in industrial sectors. This could support a shift towards green hydrogen and strengthen the case for investment in low-carbon hydrogen infrastructure.

This growth, however, raises important cross-cutting risks. Green hydrogen production using electrolysis is highly water-intensive, which poses challenges in already water-stressed countries like Armenia and Azerbaijan where expansion could worsen existing scarcity (IRENA and Bluerisk, 2023; OECD, 2024), highlighting how hydrogen's expansion requires integrated water and energy planning to ensure that ambitions align with long-term resource sustainability. At the same time, while water stress is a valid concern, hydrogen's overall water use is relatively low and needs to be seen in the context of wider industrial demands. Water stress is often localised, and production of blue hydrogen typically requires more water than that of electrolytic hydrogen (IRENA, 2025e; Rocky Mountain Institute, 2023).

Table 5.3 Key performance indicators for hydrogen

	PLANNED ENERGY SCENARIO			DECARBONISING ENERGY SCENARIO		
	2030	2040	2050	2030	2040	2050
Total hydrogen consumption (Mt)	0.7	0.9	1.2	0.7	1.1	1.7
Total hydrogen production (Mt)	0.7	1.2	1.8	0.7	2.1	4.3
Total clean hydrogen production (Mt)	0.2	0.3	0.6	0.3	1.8	4.1
Total hydrogen exports (Mt)	0	0.3	0.6	0	0.9	2.5
Total electrolyser capacity (GW)	0	2	3	0	6	14
Hydrogen production from electrolysers (Mt)	0.1	0.2	0.4	0.2	0.8	1.7
Share of green hydrogen (biomass and electrolytic) in total hydrogen production (%)	27	27	29	39	47	51
Share of power generation needed for production of green hydrogen and derivatives(%)	0	3	6	0	10	18

Notes: GW = gigawatt; Mt = million tonnes.

Table 5.3 outlines key indicators for hydrogen demand, production, and infrastructure development in the EaP region, including specific metrics for green hydrogen. Total hydrogen consumption (in terms of both gaseous hydrogen and derivative fuels) is expected to grow from 0.7 Mt in 2030 to 1.2 Mt in 2050 under the PES, and up to 1.7 Mt in the DES, reflecting rising demand in industry and transport. To meet this demand, production will rise from 0.7 Mt in 2030 to 1.8 Mt (PES) and 4.3 Mt (DES) in 2050. The surplus in the DES allows for growing exports, which could reach 2.5 Mt by 2050, compared to 0.6 Mt in the PES.

Supporting this transformation, electrolyser capacity is set to expand from negligible levels today to 3 GW in the PES and 14 GW in the DES by 2050. Electrolytic hydrogen production, in turn, will grow to 0.4 Mt in the PES and 1.7 Mt in the DES by mid-century. This translates into an overall green hydrogen share (including both electrolytic and biomass derived hydrogen) of 29% and 51% of total production under the PES and DES, respectively, marking a transition from pilot efforts to industrial-scale deployment.

This scale-up will place significant demands on the power sector. The share of electricity generation required to produce green hydrogen and its derivatives will reach 6% under PES and 18% under DES by 2050. This adds complexity to power system planning, highlighting the importance of integrating flexible electrolysis loads and accelerating renewable energy deployment.

The development of green hydrogen corridors, including potential cross-border pipelines and maritime export routes, will be essential for large-scale trade, particularly with EU markets. Co-ordination with projects of mutual interest under EU frameworks could facilitate infrastructure planning and investment.

Persistent cost barriers, regulatory uncertainty, and limited infrastructure remain key challenges. Many countries in the region still lack clear permitting procedures, long-term contracts, and market integration mechanisms. These gaps limit investor confidence and slow progress on domestic and regional hydrogen development.

In addition, for countries aiming to export to the EU, compatibility with EU regulations is a critical concern. The absence of guarantees of origin, recognised standards, and alignment with EU hydrogen certification schemes further hinders the region's ability to tap into international markets.

Inconsistent tariff structures and limited third-party access to infrastructure also constrain market development.

To unlock the full potential of hydrogen, countries will need to strengthen national planning capacities, improve regulatory frameworks, and enhance co-ordination at the regional level. Tailoring approaches to national contexts (such as existing industry plans, access to renewable resources, and export readiness) will be crucial to ensure equitable development across the EaP.

5.5 THE POTENTIAL FOR REGIONAL COLLABORATION

The expansion of solar PV and wind capacity across the EaP region underlines both national ambitions and the growing need for regional co-ordination. While Ukraine leads by a wide margin in absolute capacity, driven by early investments and strong policy signals, other countries like Azerbaijan and Georgia show accelerated growth under the DES, especially between 2040 and 2050.

Disparities in renewable potential and the timing of deployment present opportunities for complementary development. For example, while Armenia, the Republic of Moldova, and Georgia remain relatively small contributors in solar and wind by 2050, the wider region can benefit from shared infrastructure, cross-border balancing, and access to regional power markets to manage variability and optimise system integration. Azerbaijan, meanwhile, is a logical leader in offshore wind, suggesting the potential for knowledge sharing and co-investment in grid inter-connections or regional transmission corridors. Notably, Azerbaijan has outlined plans for three green energy export corridors – Caspian–Black Sea–Europe, Central Asia–Azerbaijan, and Azerbaijan–Türkiye–Europe corridors – which could serve as strategic enablers of cross-border electricity trade and regional decarbonisation.

Co-ordinated planning, around grid reinforcement, storage, market coupling, and policy alignment, will be critical to unlock the full potential of variable renewables. With a collective solar PV capacity growing from just 8.3 GW in 2021 to nearly 55 GW by 2050 under the DES – coupled with onshore wind rising to 48 GW and offshore wind increasing to 16 GW over the same period, a more integrated regional energy system can offer improved resilience, flexibility, and cost efficiency.

However, future export strategies will need to account for the evolving wholesale electricity price environment in the EU. While EU long-term wholesale electricity prices under the DES are projected to stabilise at around EUR 66/megawatt hour by 2050, that pricing implies tighter margins and increased competition (IRENA, 2025a). EaP countries aiming to export power or derived products such as green hydrogen will need to remain cost-competitive.

To support this transition, governments need to establish formal inter-governmental mechanisms for joint grid planning and market rule harmonisation. Through joint initiatives and harmonised targets, the EaP region can move beyond parallel transitions towards a unified low-carbon power system, positioning itself as a strategic clean energy hub within the broader European neighbourhood. Tailoring approaches to national circumstances and regional specificities (such as market maturity, geography, and administrative capacities) will be essential to ensure equitable and feasible pathways for all EaP countries.

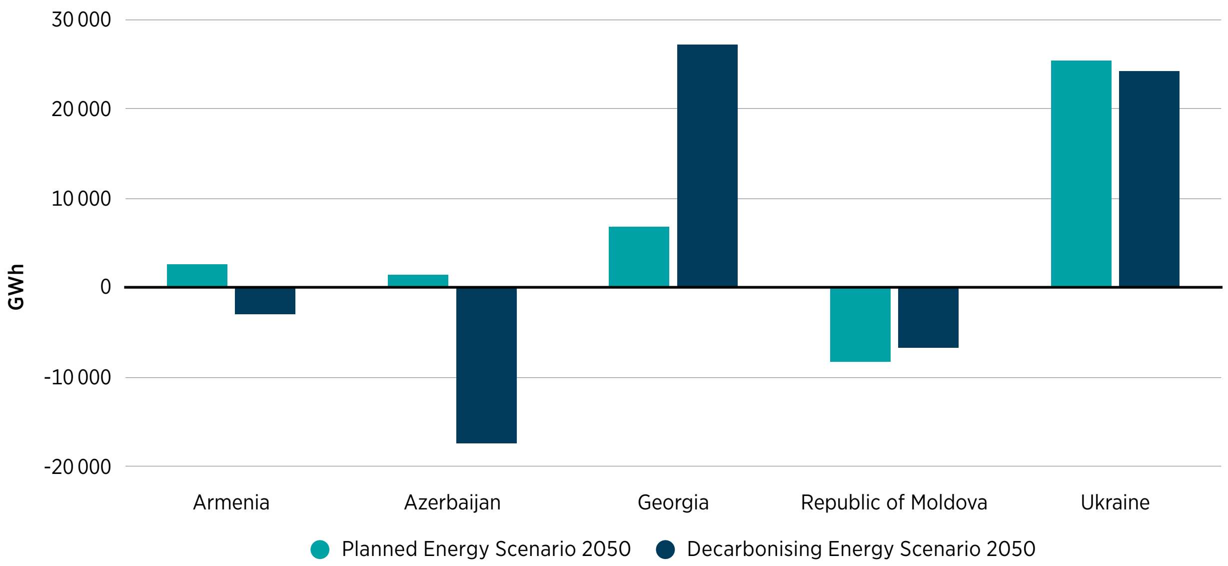
5.6 INTERNATIONAL POWER FLOWS AND BATTERY EXPANSION

International power flows

As power systems across the EaP region evolve, cross-border electricity trade becomes central to the energy transition, particularly under the DES. Unlike the more contained trade dynamics of the PES, the DES pathway is marked by a substantial increase in electricity exchange, supporting both decarbonisation and system balancing at the regional level.

Figure 5.4 illustrates this shift in flow dynamics for the year 2050. By 2050, Ukraine and Georgia emerge as the region's principal exporters, with net exports of 27 TWh and 24 TWh, respectively. This forecast reflects not only expanded renewable generation but also deeper integration into the regional power system, where power flows in both directions over many lines. Meanwhile, Azerbaijan, Armenia, and the Republic of Moldova register sustained net import positions – up to 17.5 TWh in Azerbaijan – highlighting the strategic role of secure and efficient inter-connections. In Azerbaijan's case, however, imports constitute only around 13% of total electricity demand in DES in 2050, and the country plays a broader role in the energy transition through large-scale production and export of green ammonia.

Figure 5.4 Net international power flows in the PES and DES by 2050



Note: GWh =gigawatt hour.

These developments would be supported by several key regional inter-connectors:

- The planned Black Sea Energy submarine cable, linking Georgia to Romania, will create a new East–West electricity corridor, enabling exports of renewables-based power from the South Caucasus to European markets.
- Existing connections between Georgia and Turkey, and Georgia and Armenia, already facilitate flexible cross-border trade, reinforcing Georgia's role as a regional electricity hub.
- Ukraine's and the Republic of Moldova's synchronisation with the wider European grid in 2022 marked a pivotal development, enabling electricity trade with EU markets and enhancing system resilience.
- The Republic of Moldova's inter-connectors with Romania, including Vulcănești–Isaccea, are essential to its energy security and ability to access lower-carbon electricity from the European Union.
- Armenia's ties with Iran and Georgia, though more limited in capacity, provide alternative routes for supply diversification and future regional integration.

These inter-connectors are strategic enablers of co-operation and decarbonisation. They allow renewable energy surpluses to flow to areas of high demand, support system flexibility, and reduce reliance on fossil-based domestic generation. Under the DES, where power flows increase markedly, they are indispensable elements of a secure, affordable, and low-carbon electricity future for the region.

However, countries aiming to export electricity or hydrogen to EU markets will need to navigate a changing pricing landscape. IRENA's modelling suggests that while EU wholesale prices stabilise in the long term under the DES, this may create downward pressure on EU import prices, especially if surpluses are high in the EU (IRENA, 2025a). Without clear cost advantages or provision of valuable flexibility services, EaP exports may have difficulty remaining competitive in a market characterised by abundant renewables supply and low marginal costs.

The growing role of carbon pricing, particularly within the EU Emissions Trading System, is likely to influence cross-border electricity dynamics significantly. Carbon pricing increases the competitiveness of low-carbon power and creates market signals that favour renewable generation.

The EU's Carbon Border Adjustment Mechanism, once fully implemented, may further affect regional trade patterns by placing a carbon cost on imported electricity from countries without equivalent carbon pricing regimes. This could incentivise cleaner generation in exporting countries such as Ukraine and Georgia while potentially raising the cost of more carbon-intensive imports to the European Union.

Realising this potential will depend not only investment in physical networks, but also on progress in market integration, transparent regulatory frameworks, and regional planning. Dedicated support for capacity building in national energy planning institutions may be needed to ensure co-ordinated approaches. The transition from national self-sufficiency to regional inter-dependence is no longer a distant prospect, it is an emerging reality. Inter-connectors and effective operation will be the backbone of that transformation.

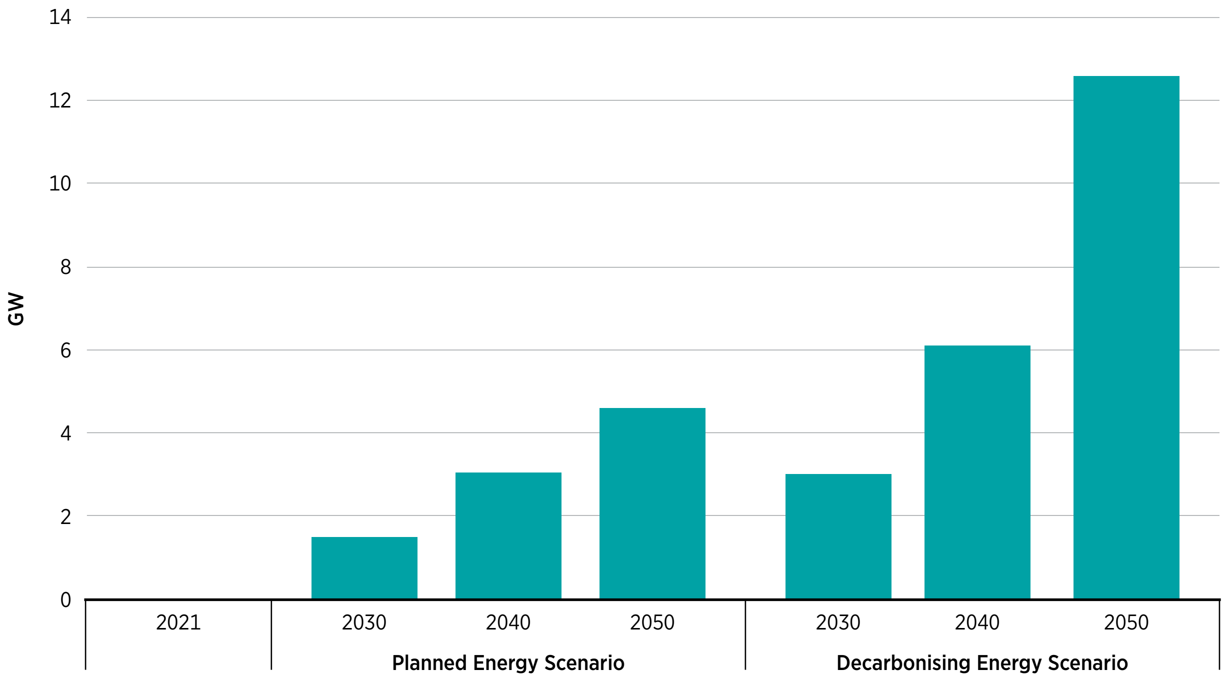
Role of storage solutions

Energy storage will be crucial in the energy transition of the EaP, enabling the integration of variable renewables and enhancing system flexibility. This role in the two scenarios is demonstrated by the expansion of battery storage capacity shown in Figure 5.5. From negligible deployment in 2021, storage capacity is projected to grow significantly under the DES, reaching 12.6 GW by 2050. Ukraine and Azerbaijan lead the expansion, reaching 6 GW and nearly 4 GW respectively, while Georgia, the Republic of Moldova and Armenia scale up to between 0.3 and 1.2 GW.

Growth on this scale emphasises the need for clear policy structures and regulatory frameworks that define the role of diverse storage solutions in power systems and incentivise and value its role in system flexibility. These include not only battery technologies, but also innovative solutions such as thermal, pumped hydro, and other emerging options. Regulatory measures need to create space for storage in electricity and ancillary service markets, supported by appropriate compensation mechanisms. Investment will depend on stable market signals, grid planning aligned with flexibility needs, and access to finance, especially for early-stage and innovative projects.

Meaningful expansion will depend on storage solutions being treated as a strategic infrastructure asset, critical to meeting rising electricity demand, integrating renewables, and enhancing energy security across the region.

Figure 5.5 Installed battery capacity in the two scenarios through 2050



Note: GW = gigawatt.

5.7 KEY ACTIONS AND PRIORITIES IN THE POWER SECTOR

Table 5.4 outlines priority actions needed across the EaP to accelerate power sector decarbonisation. Meeting growing power demand and scaling up green hydrogen production will require not only faster deployment of renewables but also substantial investments in system flexibility, cross-border infrastructure and digital grid management. Rising demand for electricity, driven by electrification of end-use sectors and green hydrogen production, demands proactive grid reinforcement, storage integration, and improved market co-ordination. The actions presented here will be key to delivering the future outlined in the DES.

Table 5.4 Key actions and priorities in power sector and green hydrogen

OUTCOMES	MEASURES AND ACTIONS SUGGESTED
High renewable share in electricity generation	• Streamline and digitalise permitting to reduce delays • Promote cross-border co-ordination for resource sharing and grid use • Align national energy strategies with regional decarbonisation goals and available EU funding tools • Improve auction design to reflect investor needs and technology-specific risk profiles
Enhanced grid flexibility	• Prioritise pilot projects in battery storage • Invest in digital grid upgrades (*e.g.* smart metering, SCADA (supervisory contral and data aquisition) systems) • Provide incentives for early investment in grid infrastructure, especially when enabled with donor support
Phasing out coal	• Secure transition funding from international donors for coal-dependent regions • Support worker re-skilling and local business development • Re-purpose coal sites for renewables, storage, or industrial re-development
Cross-border electricity market integration	• Align technical standards with the European Network of Transmission System Operators for Electricity (ENTSO-E) to ease future market coupling • Expand inter-connectors (*e.g.* Georgia–Black Sea, Republic of Moldova–Romania) • Set up joint planning bodies for co-ordinated infrastructure and market design
Growth in offshore and large-scale renewables	• Prioritise scalable land-based wind and solar as offshore wind remains cost-prohibitive • Create public-private partnership frameworks with risk guarantees to attract investors • Establish joint research and development initiatives with EU partners on solar and wind innovation
Hydrogen development	• Support green hydrogen pilots linked to industrial use • Adopt standards compatible with EU hydrogen certification • Further explore export opportunities via future hydrogen corridors • Address regulatory barriers to hydrogen deployment, including licensing, network access, and tariff structures
Energy storage expansion	• Mandate integration of storage in new solar and wind projects • Modernise distribution grids to support decentralised storage and flexible demand
Electric vehicle smart charging	• Focus on electrifying public transport and municipal fleets • Set targets for bi-directional charging infrastructure • Introduce standards and certification for vehicle-to-grid systems
System resilience and reliability	• Reinforce ageing grids in rural and mountainous areas • Expand micro-grids and distributed solar in isolated communities • Strengthen supply chains for key components (*e.g.* transformers, control systems) • Facilitate the establishment of renewable energy communities and promote prosumers • Incorporate regional specificities and national constraints into resilience planning frameworks
Low-carbon power sector	• Launch competitive auctions for renewables with concessional financing • Introduce carbon pricing to send a clear price signal for decarbonisation, with revenues reinvested in clean energy • Promote circular economy practices for renewable technologies (*e.g.* recycling of panels, turbines) • Strengthen national energy planning capacities to align long-term visions with regional integration goals

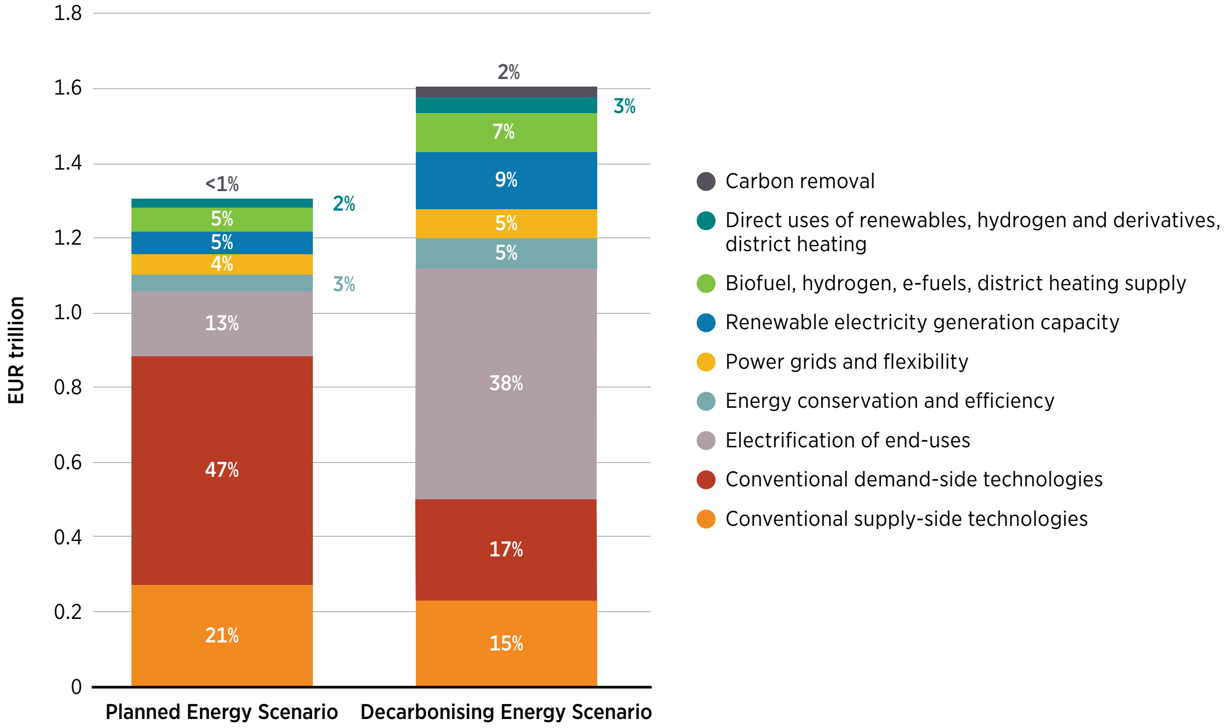
6

INVESTMENT NEEDS

The Planned Energy Scenario (PES) would require a cumulative investment of EUR 1.3 trillion through 2050, as shown in Figure 6.1. To reach the objectives proposed in the Decarbonising Energy Scenario (DES), the figure would rise to EUR 1.6 trillion for the period 2025-2050, or an annual investment of approximately EUR 62 billion. This amount is what would be necessary to build a decarbonised, modern, secure, and competitive economy in the Eastern Partnership (EaP) countries.

Annual investment in the DES is 1.2 times higher than what is required in the PES between 2025 and 2050. It encompasses energy transition infrastructure, reflecting essential transformations to decarbonise the end-use sectors and accelerate deployment of renewable energy. It also covers grid modernisation and the development of carbon capture and storage technologies. Electrification of transport (including charging infrastructure) and buildings makes up about 62% of the region's total investment needs.

Figure 6.1 Cumulative investment requirement over the period 2025-2050



Notes: Conventional demand-side technologies include ICE vehicles and conventional appliances used in the buildings sector – *i.e.* natural gas boilers and cookstoves and incandescent lighting, among others. Conventional supply side technologies include fossil-fuel based power, heating and fuels plants for the production and processing of fossil fuels.

The scale of the cumulative investment required in the DES is 7.8 times the EaP countries' 2021 GDP. While this represents a substantial need for investment, the difference compared to the PES, which requires 6.4 times the 2021 GDP, is relatively modest. Moreover, the long-term socio-economic and environmental benefits of the DES pathway are expected to far outweigh these additional upfront costs. Investments should be directed towards the highest emitters and energy consumers. In 2021, industry, transport and buildings (in descending order) were the largest emitters in the region. For that reason, special attention should be paid to decarbonising their energy consumption. Emissions from power generation and heat supply exceed those from industry, so increasing the penetration of renewables in the energy supply is key to reducing the region's emissions.

At the country level, transport and buildings are the two largest emitters and energy consumers, followed by industry, in Armenia, Azerbaijan, Georgia and the Republic of Moldova. In Ukraine the two largest emitters and energy consumers are industry and transport, followed by buildings. Each country must prioritise investments for decarbonisation of the end-use sector(s) that have the highest emissions and energy consumption.

The decarbonisation of the transport sector will not come without costs for end users (particularly in vehicle acquisition) and for infrastructure investments. The infrastructure required for electric vehicles reaches a cumulative investment of EUR 5 billion in the PES and of EUR 27 billion in the DES, for the 2025-2050 period, which is equivalent to 3% and 13% of the EaP countries' GDP in 2021, respectively. In both scenarios, the bulk of the investment is for public charging points (78% in the PES and 55% in the DES). In the DES, depot charging points claim a greater share of the investment owing to the more extensive development of the electric truck and bus fleet (37% and 10%). Despite the wider deployment of electric vehicles in the DES compared to the PES, the average annual end-user costs for vehicles are comparable in both scenarios, amounting to EUR 24.7 billion and EUR 26 billion, respectively. This similarity in costs is largely due to the expected achievement of price parity between electric vehicles and internal combustion engine vehicles, by the early-2030s for passenger vehicles, and by the mid-late 2030s for freight vehicles.

Industry investment in the DES will rise 2.6-fold cumulatively over the PES, amounting to EUR 46 billion. This amount equates to EUR 1.8 billion annually or about 1% of the region's GDP in 2021. Investment in carbon sequestration technology dominates the investment requirement in the DES, claiming EUR 1.1 billion annually, more than 61% of total investment for industry as a whole. Electrification and energy efficiency represent about 28% of the total investment in industry, while investment in renewable energy, hydrogen and district heating together claim about 7%. By sub-sector, investment in cement and iron and steel together make up more than three-quarters of industry decarbonisation in the DES, requiring about EUR 35 billion cumulatively. Decarbonisation in the chemical and "other industries" sub-sectors claim about EUR 0.26 billion and EUR 0.13 billion each year in the DES.

Investments in the buildings sector will require EUR 312 billion in the DES between 2025 and 2050 to lower the sector's emissions to 4 $MtCO_2$ by 2050. This investment amount is 49% higher than what is expected in the PES for the same time period. Cumulative investment spending on end uses, over 2025-2050 - including for heating/cooling devices, electrical appliances and lighting- is expected to reach EUR 191 billion in the PES and EUR 247 billion in the DES. As shares of the 2021 GDP of the EaP countries, this is equivalent to 94% in the PES and 121% in the DES.

The measures implemented in space heating would absorb approximately 56% of the cumulative end-use spending in the PES and 47% in the DES over 2025-2050 mainly due to the adoption of heat pumps. Transitioning towards highly efficient appliances leads to EUR 40 billion in spending under the DES compared to EUR 18 billion in the PES, representing 16% and 10% of the overall respective cumulative spending. Lastly, as more cooling degree days and larger floor area drive up cooling needs across the EaP countries, more air-conditioning units are installed over time, representing approximately 1% of the overall spending in both scenarios.

Residential and commercial buildings call for different approaches, considering the share of stock targeted and renovation level. Under the PES, renovation requires an average of EUR 713 million a year up to 2050. Under the DES, yearly investments are almost 3.5 times higher (EUR 2.5 billion /year) because a much more ambitious pathway is pursued: doubling the annual renovation rate to 2% expands the size of the building stock targeted. Improvement of buildings' insulation leads to EUR 19 billion in cumulative spending in the PES and EUR 65 billion in the DES between 2025 and 2050. These cumulative investments represent 9% and 32% of the 2021 EaP GDP in the PES and DES, respectively.

Investments in the power sector will require approximately EUR 292 billion under the DES between 2025 and 2050 to support the expansion of renewable energy (EUR 218 billion), modernisation and expansion of grids (EUR 54 billion), and increased system flexibility (EUR 19 billion). This represents 143% of the region's GDP in the year 2021 and a 71% increase compared to the EUR 174 billion needed under the PES over the same period which corresponds to 84% of the region's GDP in the year 2021. Investments in power generation technologies, including utility-scale solar photovoltaic, onshore and offshore wind, and hydropower, are projected to reach EUR 218 billion under the DES, compared to EUR 123 billion under the PES.

Spending on flexibility options, such as battery storage facilities, grows from EUR 10 billion in the PES to EUR 19 billion in the DES, reflecting the increased role of variable generation. Onshore wind and solar photovoltaic see the largest absolute increases, with investments more than doubling under the DES. Transmission and distribution infrastructure requires EUR 54 billion in the DES and EUR 41 billion in the PES, making up around one-fifth of total power sector investment needs in both scenarios.

These investment levels reflect the scale of development required to meet rising electricity demand, enable greater electrification across sectors, and support a more integrated and reliable energy system across the region.

Actions needed to accelerate investment

The region's dependency on fossil fuel and aging infrastructure calls for accelerated investment in the energy transition. Multi-faceted actions to support the investment in the regions are the keys to mobilise funds.

- Public finance and policy should crowd in private capital, but the great geographical and technological diversity of needed investment requires targeted and scaled-up public contributions. For many years, policy has focused on mobilising private capital. However, public funding is urgently needed to invest in basic energy infrastructure in the region, as well as to drive deployment in less-mature technologies – especially in end uses such as heating, hydrogen, carbon capture and storage, and/or synthetic fuel production and in areas where private investors seldom venture. Sorely needed is the reinforcement of fiscal policies to encourage more large-scale blended finance models and de-risking instruments to attract private capital to the region. One requirement is to increase the current EaP Economic and Investment Plan, which currently stands at EUR 17 billion (European Commission, 2021).
- Clear and transparent public policies within a consistent regulatory framework are critical. Priorities should be to align country-level strategies to de-risk investment by setting binding renewable energy targets, simplifying permitting processes and eliminating fossil fuel subsidies. These regulatory frameworks will be the keys to attract private capital in the region.
- A predictable, transparent and reliable investment environment is equally essential. The Energy Community legal framework (European Commission, 2025b) offers a strong reference point, even for countries that are not formal members. Provisions such as transparent tariff methodologies and long-term network development planning help de-risk investments and create the certainty that private financiers seek. Voluntary alignment with these principles can strengthen investor confidence and support regional efforts to meet decarbonisation goals.
- Achieving the list of measures outlined under the DES requires a set of instruments to facilitate a successful transition. These include financing for final consumers (considering the local income level) and addressing the specific energy requirements of individual buildings. In this regard, state programmes for the building renovation and replacement of electrical appliances will be indispensable for achieving the sector's decarbonisation. Financing for such programmes can come from national and regional development banks, as well as from other international institutions offering financial co-operation.
- A roadmap of regional grid strategies must be a short-term priority. The roadmap would help unlock near-term grid and flexibility investments to enable the rollout of renewable energy sources and cost-effective electrification. The roadmap must be aligned with binding renewable energy targets at national and regional levels that are designed in co-ordination with the transmission and distribution system operators.
- EaP countries benefit from technical assistance or budget support from the EU to accelerate investments aligned with decarbonisation objectives. The region has much to gain from knowledge sharing and best practices, especially through the EU's financial assistance mechanisms on the climate transition and energy efficiency.
- Stronger institutional capacity and appropriate investments in monitoring, reporting, and verification systems are needed to keep track of the decarbonisation objectives in each end-use sector.

REFERENCES

CEER (2022), *Guide for investing in renewable energies in the Eastern Partnership Countries 2022*, www.ceer.eu/wp-content/uploads/2024/04/Investing-in-Renewable-Energies.pdf

Copenhagen Centre on Energy Efficiency (2015), "Accelerating Energy Efficiency Initiatives and Opportunities in Eastern Europe, Caucasus and Central Asia", Copenhagen Centre on Energy Efficiency, https://c2e2.unepccc.org/wp-content/uploads/sites/3/2016/01/c2e2-report-cis.pdf

DIW Econ GmbH (2024), *Renewable energy in Ukraine: Current institutional environment, investment barriers and prospect*, https://diw-econ.de/wp-content/uploads/JT_UA_DIW-Econ-Report_RES-in-Ukraine_v.1.0.pdf

Doronina, I., *et al.* (2024), "Why renewables should be at the center of rebuilding the Ukrainian electricity system", *Joule*, vol. 8/10, pp. 2715–20, https://doi.org/10.1016/j.joule.2024.08.014

Doronina, I., *et al.* (2025), "GIS-based analysis for identifying priority regions and developing renewable energy in post-war Ukraine", *Renewable Energy*, vol. 247, pp. 122970, https://doi.org/10.1016/j.renene.2025.122970

Energy Charter Secretariat (2015), *In-Depth Review of the Energy Efficiency Policy of Armenia*, www.energycharter.org/fileadmin/DocumentsMedia/EERR/ARMENIA_IDR_2017_Final_EN.pdf

Energy Community (2024a), "Moldova Annual Implementation Report", Energy Community, www.energy-community.org/dam/jcr:1ada75bb-8fee-4905-9e55-b0c4c636fa56/IR2024_Moldova.pdf

Energy Community (2024b), *Post War Development of the Renewable Energy Sector in Ukraine*, https://energy-community.external.syracus.net/dam/jcr:063d888c-dd3d-469c-a2b3-68d6130b30f5/intec%202024%20UA%20post%20war%20RE%20Develoment.pdf

European Commission (2019), "Directive (EU) 2019/944 on Common Rules for the Internal Market for Electricity", https://eur-lex.europa.eu/legal-content/EN/TXT/HTML/?uri=CELEX:32019L0944

European Commission (2021), "Recovery, resilience and reform: post 2020 Eastern Partnership priorities", www.eeas.europa.eu/sites/default/files/swd_2021_186_f1_joint_staff_working_paper_en_v2_p1_1356457_0.pdf

European Commission (2025a), *Carbon Border Adjustment Mechanism*, https://taxation-customs.ec.europa.eu/carbon-border-adjustment-mechanism_en

European Commission (2025b), "Energy Community", https://energy.ec.europa.eu/topics/international-cooperation/international-organisations-and-initiatives/energy-community_en#the-energy-community-treaty

Georgian State Electrosystem (2024), *Ten-Year Network Development Plan of Georgia 2024-2034*, www.gse.com.ge/sw/static/file/TYNDP_GE-2024-2034_ENG.pdf

German Economic Team (2024), *Energy sector monitor Armenia 2024*, www.german-economic-team.com/wp-content/uploads/2024/07/GET_ARM_PB_02_2024_EN.pdf

Government of Armenia (2004), "The Law of the Republic of Armenia on Energy Saving and Renewable Energy", www.parliament.am/legislation.php?sel=show&ID=2119&lang=eng

Government of Armenia (2020), *Republic of Armenia Energy Sector Development Strategic Program to 2040*, https://policy.asiapacificenergy.org/sites/default/files/Energy%20Sector%20Development%20Strategic%20Program%20to%202040%20.pdf

Government of Armenia (2022), *Program on Energy Saving and Renewable Energy for 2022-2030 for Armenia*, https://eu4climate.eu/download/program-on-energy-saving-and-renewable-energy-for-2022-2030-for-armenia/

Government of Armenia (2023), "Long-term (until 2050) low emissions development strategy of the Republic of Armenia"

Government of Armenia (2024), "Strategy draft for electric mobility development in Armenia"

Government of Azerbaijan (2021), "Law on the Use of Energy Resources and Energy Efficiency", https://e-qanun.az/framework/48129

Government of Azerbaijan (2023), "The Republic of Azerbaijan Updated document on Nationally Determined Contributions (NDC)", Government of Azerbaijan.

Government of Azerbaijan (2024), "National plan on electromobility: 2025-2030 draft"

Government of Georgia (2019), "National Renewable Energy Action Plan: Georgia", www.economy.ge/uploads/files/2017/energy/samoqmedo_gegma/nreap_v_3_eng_21022020.pdf

Government of Georgia (2023), "Integrated National Energy and Climate Plan of Georgia", www.energy-community.org/dam/jcr:4dfd3e00-78c0-47a8-a2d9-01ec62459010/National__Energy_and_Climate_Plan_of_Georgia_(DRAFT)%20(2).pdf

Government of the Republic of Armenia (2023), "Long-term low greenhouse gas emission development strategy of the Republic of Armenia (unitl 2050)", https://unfccc.int/sites/default/files/resource/UNDP%20LT_LEDS_ARMENIA.pdf

Government of the Republic of Moldova (2012), *Energy Strategy of the Republic of Moldova to the year 2030*, Approved by the Government Decision no. 102 of 05.02.2013, Ministry of Economy and Infrastructure, Chisinau, https://mei.gov.md/en/content/energy

Government of the Republic of Moldova (2023), "National Energy and Climate Action Plan of the Republic of Moldova 2025-2030", https://cned.gov.md/sites/default/files/document/attachments/necpm2025-2030_en_final_.pdf

Government of Ukraine (2024a), "National Energy and Climate Plan of Ukraine 2025-2030", https://me.gov.ua/download/2cad4803-661e-4ae9-9748-3006d6eb3e1c/file.pdf

Government of Ukraine (2024b), *Hydrogen Strategy of Ukraine*, https://mev.gov.ua/sites/default/files/field/file/proekt-rozporyadzhennya_0.pdf

ICAO, *et al.* (2023), "ICAO's 2050 net-zero CO_2 goal for international aviation", https://theicct.org/wp-content/uploads/2022/12/global-aviation-ICAO-net-zero-goal-jan23.pdf

IEA (2021), "Azerbaijan Energy Policy Review", International Energy Agency, www.oecd.org/content/dam/oecd/en/publications/reports/2021/07/azerbaijan-2021-energy-policy-review_c4bd98ee/90fa056d-en.pdf

IEA (2022a), *2022 Armenia Energy Policy Review*, International Energy Agency, https://iea.blob.core.windows.net/assets/8328cc7c-e65e-4df1-a96f-514fdd0ac31e/Armenia2022EnergyPolicyReview.pdf

IEA (2022b), "Moldova 2022 Energy Policy Review", International Energy Agency, https://iea.blob.core.windows.net/assets/dc881e93-9f82-4072-b8b4-a0d00a487f59/Moldova2022.pdf

IEA (2024), *Energy Efficiency Policy in Azerbaijan: A Roadmap*, International Energy Agency, https://iea.blob.core.windows.net/assets/fe63a883-2b61-426f-bdab-85b49576fdf9/EnergyEfficiencyRoadmapforAzerbaijan.pdf

IEA (2025), "Global Energy Review: CO_2 Emissions in 2021", International Energy Agency, https://iea.blob.core.windows.net/assets/c3086240-732b-4f6a-89d7-db01be018f5e/GlobalEnergyReviewCO2Emissionsin2021.pdf

IMO (2025), "IMO approves net-zero regulations for global shipping", International Maritime Organization, www.imo.org/en/MediaCentre/PressBriefings/pages/IMO-approves-netzero-regulations.aspx

IRENA (2020), *Renewables readiness assessment: Republic of Azerbaijan*, International Renewable Energy Agency, Abu Dhabi, www.irena.org/publications/2020/Mar/RRA-Azeri

IRENA (2024), *World energy transitions outlook 2024: 1.5°C pathway*, International Renewable Energy Agency, Abu Dhabi, www.irena.org/Publications/2024/Nov/World-Energy-Transitions-Outlook-2024

IRENA (2025a), *Regional energy transition outlook: European Union*, International Renewable Energy Agency, Abu Dhabi, www.irena.org/Publications/2025/Jun/Regional-energy-transition-outlook-European-Union

IRENA (2025b), *Policies for advancing the renewables-based electrification of road transport*, International Renewable Energy Agency, Abu Dhabi, www.irena.org/Publications/2025/Jun/Policies-for-advancing-the-renewables-based-electrification-of-road-transport

IRENA (2025c), *Energy transition assessment: Georgia*, International Renewable Energy Agency, Abu Dhabi, www.irena.org/Publications/2025/Apr/Energy-transition-assessment-Georgia

IRENA (2025d), *Investment opportunities for utility-scale solar and wind areas: Georgia zoning assessment*, International Renewable Energy Agency, Abu Dhabi, www.irena.org/Publications/2025/May/Investment-opportunities-for-utility-scale-solar-and-wind-areas-Georgia-zoning-assessment

IRENA (2025e), *Green hydrogen for industrial decarbonisation: Central Asia and the South Caucasus*, International Renewable Energy Agency, Abu Dhabi, www.irena.org/Publications/2025/May/Green-hydrogen-for-industrial-decarbonisation-Central-Asia-and-the-South-Caucasus

IRENA and Bluerisk (2023), *Water for hydrogen production*, International Renewable Energy Agency and Bluerisk, Abu Dhabi, www.irena.org/Publications/2023/Dec/Water-for-hydrogen-production

Ministry of Energy of Azerbaijan (2021), *Law on the use of renewable energy sources in electricity generation*, https://e-qanun.az/framework/47842

Ministry of Energy of Ukraine (2023), "Clean Energy Roadmap: From Reconstruction to Decarbonization in Ukraine. Report for COP28", www.pnnl.gov/sites/default/files/media/file/Ukraine%20NZW%20COP28%20report%202023.pdf

Moldelectrica (2018), *Electricity transmission network development plan for 2018-2027 period*, https://moldelectrica.md/files/docs/TYNDP_EN.pdf

National Statistics Office of Georgia (2022), "Energy Consumption in Households: in Georgia", National Statistics Office of Georgia, www.geostat.ge/media/52116/Publication_Energy-Consumption-in-Households.pdf

OECD (2024), *Environment at a Glance in the EU Eastern Partnership Countries: Measuring Progress Towards a Green Transformation*, www.oecd.org/content/dam/oecd/en/publications/reports/2024/06/environment-at-a-glance-in-the-eu-eastern-partnership-countries_9c587c94/aa7c00b1-en.pdf

REPORT (2024), “Azerbaijan initiates creation of green corridor on route from China to Europe”, https://report.az/en/infrastructure/azerbaijan-initiates-creation-of-green-corridor-on-route-from-china-to-europe/

Republic of Azerbaijan, M. O. E. (2024), “Azerbaijan National Hydrogen Strategic Outlook”, https://enerjiportali.az/wp-content/uploads/2025/02/Azerbaijan-National-Hydrogen-Strategic-Outlook-Rev_14.02.2025.pdf

Rocky Mountain Institute (2023), *Hydrogen Reality Check: Distilling Green Hydrogen's Water Consumption*, https://rmi.org/hydrogen-reality-check-distilling-green-hydrogens-water-consumption/

USAID (2022), “Armenia least cost energy development plan: 2024–2050”, https://rise.esmap.org/data/files/library/armenia/Energy%20Efficiency/Armenia_%20Least%20Cost%20Energy%20Development%20Plan.pdf

World Bank (2020a), “Energy Efficiency Retrofitting of Residential Buildings: Solutions and Recommendations”, https://documents1.worldbank.org/curated/en/720901591357951282/pdf/Tbilisi-Urban-Regeneration-Energy-Efficiency-Project-Second-Phase.pdf

World Bank (2020b), *Technical Potential for Offshore Wind in Ukraine Map*, https://documents1.worldbank.org/curated/en/709391586844502062/pdf/Technical-Potential-for-Offshore-Wind-in-Ukraine-Map.pdf

World Bank (2022), *Offshore Wind Roadmap for Azerbaijan*, World Bank, Washington, D.C., https://documents1.worldbank.org/curated/en/099125006022242537/pdf/P1757160c9ba20078097880a-6781b95d5eb.pdf

World Bank (2023), *Azerbaijan Country Climate and Development Report*, https://openknowledge.worldbank.org/entities/publication/8dd535d5-126a-4181-8ffe-c0fa49b2599f

IRENA

International Renewable Energy Agency

www.irena.org