EUROPE AND
CENTRAL ASIA

ARMENIA

World Bank Group

COUNTRY CLIMATE AND DEVELOPMENT REPORT

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This Country Climate and Development Report (CCDR) is a collaborative effort of the World Bank, International Finance Corporation (IFC), and the Multilateral Investment Guarantee Agency (MIGA). It was produced by a core team led by Julie Rozenberg, Léa Hakim, and Joern Huenteler.

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Acronyms and Abbreviations

AMD	Armenian drams
APS	announced policies scenario
ARMSTAT	Statistical Committee of the Republic of Armenia
BCR	benefit-cost ratio
CAPEX	capital expenditure
CBAM	Carbon Border Adjustment Mechanism
CCDR	Country Climate and Development Report
CEPA	Comprehensive and Enhanced Partnership Agreement
CGE	computable general equilibrium
CO2	carbon dioxide
CP	carbon price
CPAT	Climate Policy Assessment Tool
CPEIR	Climate Public Expenditure and Institutional Review
CSA	climate-smart agriculture
ESDS	Energy Sector Development Strategy
ESG	environmental, social and governance
ESRE	Energy Saving and Renewable Energy (Programme)
EU	European Union
GDP	gross domestic product
GHG	greenhouse gas
GW	gigawatt(s)
HBB	higher biomethane blending (scenario)
ICT	information and communications technology
IEc	Industrial Economics
IFI	international financial institution
IPPU	industrial processes and product use
LT-LEDS	Long-term Low Greenhouse Gas Emissions Development Strategy
MAB	multiple-apartment building
MANAGE-WB	World Bank's Mitigation, Adaptation and New Technologies Applied General Equilibrium model
MoE	Ministry of Environment
MoEc	Ministry of Economy
MoF	Ministry of Finance
MOTAI	Ministry of Territorial Administration and Infrastructure
MtCO2e	million tonnes of carbon dioxide equivalent
MWh	megawatt hour(s)
NAP	national adaptation plan
NDC	nationally determined contributions
NNS	no-nuclear scenario
NPV	net present value
NZS	net zero scenario
OPEX	operating expenditure
PIM	public investment management
PM2.5	fine particulate matter
pp	percentage points
PPA	power purchase agreement
PPP	public-private partnership
PV	photovoltaic
RE	renewable energy
REF	reference (scenario) with current gas prices
REF-IG	reference (scenario) with international gas prices
RIOS	Resource Investment Optimization System
SAP	sectoral adaptation plan

SFH	single family home
SLR	solar land-use restriction (scenario)
SOE	state-owned enterprise
SP	social protection
tCO2	tonne(s) of carbon dioxide
tCO2e	tonne(s) of carbon dioxide equivalent
TCP	total carbon price
TWh	terawatt hour(s)
UNFCCC	United Nations Framework Convention on Climate Change
VAT	value-added tax
WUA	water user association

$ all dollar amounts are US dollars

Executive Summary

MAIN MESSAGES

- Climate action in Armenia brings new opportunities for greener and faster growth, energy security, and resilience.
- Priorities for achieving decarbonization objectives and energy security are strengthening the electricity grid to scale up solar energy, improving energy efficiency in buildings, and electrifying heating and transport.
- Priorities to boost agriculture productivity, food security, and resilience are water efficiency and conservation, early warning systems in agriculture, and strengthening critical infrastructure.
- Fiscal and institutional reforms are key to support private sector transitions and accelerate growth, as is social protection to protect the most vulnerable.

Why climate mitigation and adaptation matter for Armenia

Armenia's economy is fueled by imported natural gas. The country's power, heating, and transport sectors rely heavily on natural gas, and the energy intensity of Armenia's gross domestic product (GDP) is higher than the global average. Natural gas represents up to 63 percent of Armenia's total energy supply, one of the world's largest shares, and all of it is imported, mostly from the Russian Federation, creating a high vulnerability to external shocks. The high share of natural gas puts Armenia below the global average in terms of greenhouse gas (GHG) emissions, at 3.8 tonnes of carbon dioxide equivalent (tCO2e) per capita in 2019, driven by the energy sector (two third of emissions) followed by the agriculture sector.

Decarbonization provides energy security at zero or even negative costs, when considering the full economic costs of fossil fuels, and acts as an insurance against the uncertainty around future gas prices. Energy security risks provide a clear incentive for Armenia to develop domestic renewable resources. As gas has historically been imported at relatively low costs (the current price of $180 per 1,000 standard cubic meters is substantially below international gas price benchmarks), an increase in natural gas prices to meet international benchmarks would immediately make the low-carbon transition a no-regret decision. A scenario in which Armenia diversifies its gas imports and pays international gas prices would lead to a higher energy system cost than a decarbonization scenario in which Armenia transitions from a gas-powered to a solar-powered economy and reduces emissions to its target of 2.07 tCO2e per capita by 2050.

Decarbonization would also improve air quality and reverse severe land and forest degradation. Armenia's high reliance on natural gas and the high energy intensity of its GDP contribute to air pollution, with the annual costs of damage to health from fine particulate matter (PM2.5) pollution reaching as much as 10.6 percent of GDP. Land degradation is also high, aggravated by high deforestation rates (70 percent of Armenia's forests are degraded), driven by mining and illegal logging, and by rural populations' high reliance on firewood for heating. Action to decarbonize the energy sector—particularly transport and heating—will have significant positive spillovers in terms of reducing air pollution. Together with actions to reduce emissions from deforestation and land degradation, decarbonizing the energy sector will reduce PM2.5 concentration by almost 8 micrograms per cubic meter of air in 2060, or about 25 percent of 2020 concentrations. This corresponds to a 75 percent reduction in mortality from air pollution attributed to fossil fuels and a 2 percent reduction in mortality due to windblown dust by 2060. Meanwhile, energy decarbonization, sequestration, climate-smart agriculture (CSA), and other decarbonization efforts can

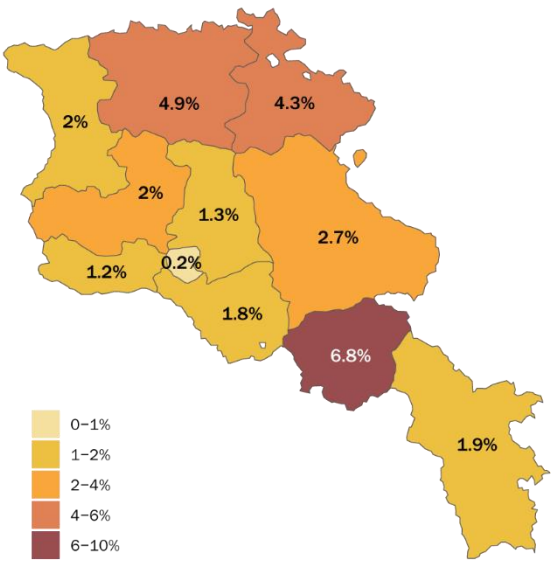
help reduce deforestation and enrich landscapes, with spillovers including increasing the economic contribution and adaptation capacity of ecosystem services.

Armenia's pre-existing water stress underlines the urgency of investments in climate adaptation. The country is already water-stressed. In the Ararat Valley, groundwater abstraction for commercial fish farming and irrigation exceeds annual recharging. To satisfy demand for irrigation, authorized releases from Lake Sevan largely exceed historical natural outflow. The water supply system suffers from significant water losses in both irrigation (20–67 percent) and municipal water supplies, where losses represent 70 percent of supply, on average. Climate change will exacerbate these trends and reduce water availability for irrigation (with unmet water demand above 50 percent in some basins in 2050) and agriculture yields. A dry/hot future could lead to a 37 percent decline in yields for rainfed crops, 25 percent decline for irrigated crops, and 20 percent decline for cattle, goat, and sheep production around 2050. Climate change will also worsen land degradation, resulting in $363 million in foregone agricultural production, which is more than double the current impacts of degradation. It could also increase the intensity of floods, which already cost the country 0.8–2.3 percent of GDP annually in asset damages (figure S1a).

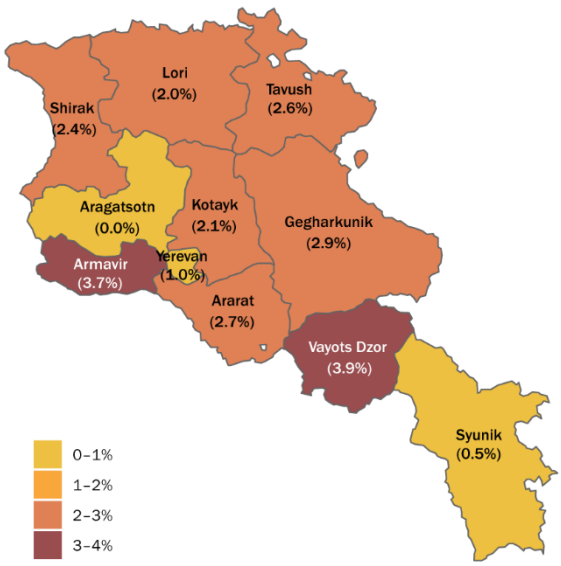
Investing in climate adaptation also brings benefits in terms of food security and avoided increases in poverty. Climate adaptation can eliminate future water deficits for the agriculture sector and increase both agriculture yields and food security by enabling a prompt response to climate or economic shocks. Increased resilience and productivity in the agriculture sector and food security are strong foundations for expanding the fast-growing domestic food processing industry, which is a significant contributor to job creation and export revenues. It can also help the country avoid a 2.7 percentage point increase in poverty in 2030 due to climate shocks, compared to a reference scenario with current gas prices (figure S1b). Land degradation hotspots and the highest climate change impacts on unmet water demand for irrigation are in provinces (marzes) with high poverty. Well-targeted adaptation policies can reverse these regional disparities and reduce poverty while increasing resilience. Similarly, policies can be targeted towards women, who tend to be more vulnerable to climate shocks due to lower access to land and dwelling ownership.

Figure S.1: Selected climate risks, by marz

a) Average annual losses due to floods, 2020



b) Share of population falling into poverty by 2030 due to climate change impacts on water and agriculture

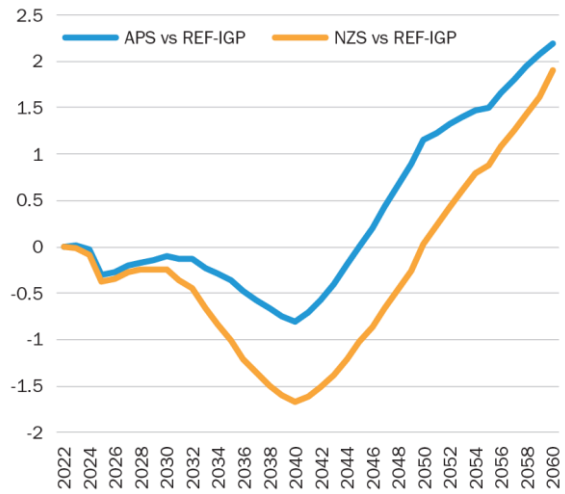


Sources: World Bank staff calculations, based on data from Fathom flood maps, Industrial Economics (IEc), the World Bank's Mitigation, Adaptation and New Technologies Applied General Equilibrium model (MANAGE-WB), and the Statistical Committee of the Republic of Armenia ARMSTAT 2023.

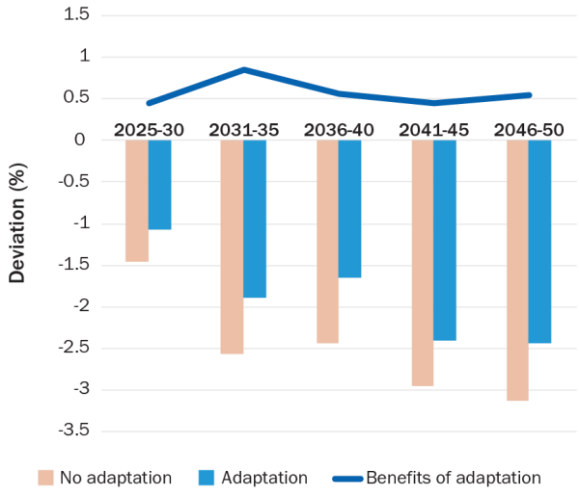
Smart climate action can have a positive effect on growth. Analysis based on a computable general equilibrium model shows that decarbonization can be achieved with minimal short-term impact on GDP and an acceleration of growth after 2040, while adaptation would have a positive impact on GDP (figure S2). Under the net zero scenario (NZS), the economy contracts in the short to mid-term due to high levels of investment, peaking at -3.6 percent in the 2040s, compared to the REF scenario, and at -1.7 percent when compared to a reference scenario with international gas prices (REF-IGP scenario). Growth accelerates after 2040, with GDP almost catching up with the REF scenario and 2 percent higher than the REF-IGP scenario in 2060. The benefits of reducing air pollution increase GDP by another 1 percent per year by 2060, while the benefits of adaptation increase it by at least another 0.5 percent per year between 2030 and 2060.

Figure S.2: Macroeconomic benefits of mitigation and adaptation strategies (real GDP)

a) Deviation from the REF-IGP scenario in the Announced Policies Scenario (APS) and NZS, following the mitigation strategy



b) Deviation from REF scenario under the hot/dry scenario with and without adaptation



Source: World Bank staff calculations, using MANAGE-WB
Notes: The benefits of adaptation are shown only for the worst-case scenario; in a milder climate change scenario, the adaptation strategy would completely reverse climate impacts.

Climate action presents opportunities for Armenia for greener, more productive, and more sustainable growth, driven by a more innovative private sector. The country's long-term vision, set out in the *Armenia Transformation Strategy 2050*, is to shift to a knowledge-intensive, innovative, and green economic model, illustrated by the developing success of the information technology services sector, which accounted for $1.1 billion in exports in 2023. The environmental services sector can thrive on the backbone of a robust services sector driven by information and communications technology and provide a significant opportunity to increase the share of value added—for example, through the solar photovoltaic (PV) value chain. Investing in CSA and developing high-value horticulture and other agricultural value chains offers potential to increase export diversification while supporting rural economies and enhancing domestic food security. Achieving this vision is closely tied to the private sector's ability to adapt and innovate in response to the global sustainability shift, and a strategic regulatory environment for job-creating export sectors with growing potential, such as high-demand critical rare minerals, or textiles and apparel, where the country has a competitive advantage due to its lower GHG emissions compared to major producers. Increasing integration with European Union (EU), other regional, and global markets and institutions would support such opportunities.

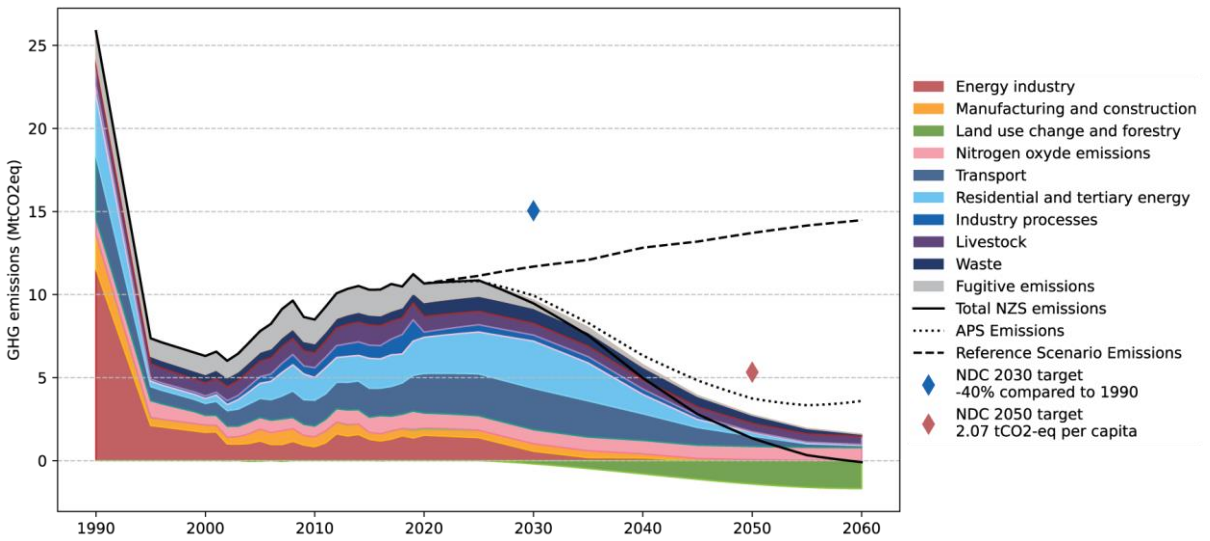
Achieving these opportunities will require investments and a concerted package of policy actions. This includes investment and policy needs for mitigation (priority 1) and adaptation (priority 2), as well as

enabling macrofiscal and institutional reforms that can facilitate the transition and support the financing of these investments (priority 3).

Policy priority 1 (mitigation): Achieve decarbonization objectives and energy security by strengthening the electricity grid to scale up solar energy, increasing energy efficiency in buildings, and electrifying heating and transport.

To achieve its 2050 emission target of 2.07 tCO2e per capita, Armenia needs to raise its near-term ambition and rapidly accelerate policy implementation. Its latest nationally determined contribution (NDC) to the United Nations Framework Convention on Climate Change, adopted in 2021,[1] set an economywide target of reducing GHG emissions by 40 percent below 1990 levels by 2030, while its Long-term Low Greenhouse Gas Emissions Development Strategy, adopted in December 2023, reaffirms the government's ambition to reduce per capita GHGs to 2.07 tCO2e by 2050. Modeling results for this report suggest that, in the absence of additional reforms, GHG emissions from Armenia's energy-related activities and industrial processes and product use would remain 62 percent lower than 1990 levels in 2030, well below the NDC target of 40 percent reduction (figure S3). But under the REF scenario, it would not achieve the long-term GHG emissions target for 2050, announced in its NDC. To reach this ambitious target, Armenia needs to set a 2030 target of reducing GHGs by at least 65 percent compared to 1990 levels, and substantially increase the ambition of its near-term climate mitigation policies (figure S3).

Figure S3: Modeled net zero GHG emission trajectory (by sector), compared to the REF scenario, APS, and current NDC targets for 2030 and 2050



Source: World Bank staff calculations, based on modeling done for this report.

Armenia will need to invest $3 billion in the electricity sector to transition from a natural gas-based to a solar-powered economy. The energy system APS and NZS illustrate how the country can leverage its power sector to decarbonize the economy through electrification. Solar PV investments would lead the way, reaching 1 and 4 gigawatts (GW) by 2030 and 2040, respectively under the APS, or 1.7 and 5.2 GW, respectively, under the NZS. To absorb these quantities of solar power, Armenia would need

[1] Government Decision N 610 – L of 22 April 2021, Nationally Determined Contribution 2021–2030 of the Republic of Armenia to Paris Agreement (https://unfccc.int/sites/default/files/NDC/2022-06/NDC%20of%20Republic%20of%20Armenia%20%202021-2030.pdf). The government plans an update for 2025–35 by November 2025.

substantial parallel investments in international grid interconnections, domestic grid reinforcement, and energy storage. Battery storage solutions would be crucial in the near-term, reaching 1.8 GW by 2030 under the APS, or 3.1 GW under the NZS. Hydropower will play a modest role in decarbonizing the energy sector, as production capacity could only increase marginally, while electricity demand for heating and transport would increase rapidly under the NZS. Nuclear contributes about 11 percent of power generation by 2060, or 4.3 terawatt hours (TWh), down as a share from about 35 percent (2.6 TWh) today.

The transition entails risks of stranded assets in gas distribution and gas-fired power generation. Carbon pricing is likely to encourage customers to shift to electricity for heating and cooking. The low-pressure parts of the gas distribution network, which have seen substantial investment over the past decades, are therefore at risk of becoming stranded assets if Armenia cannot produce zero-carbon gases, such as hydrogen and renewable methane, that are cheap enough for the small consumers that make up the bulk of consumption. The government can closely monitor how demand for gas in the distribution network develops and, in parallel, invest in pilots for developing low-carbon gases to assess their economic viability. If the economics of gas consumption look likely to become unviable, the government can plan for a gradual, managed phase-out to mitigate fiscal contingent liabilities. The risk of stranded assets in thermal power generation could also be significant, but modeling in this Country Climate and Development Report (CCDR) suggests that the value of dispatchable gas-fired generation is likely to increase substantially in the market, so gas power plants may retain or increase profitability, even with lower use.

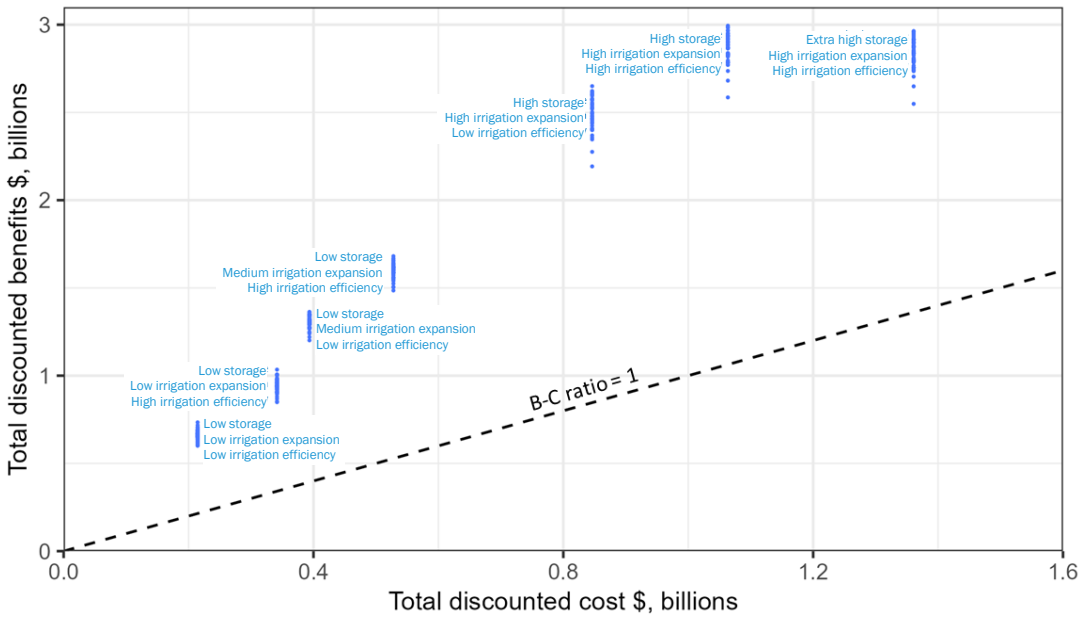
Investing an additional $200 million to electrify road transport and expand public transport could substantially reduce transport sector emissions and urban air pollution. Decarbonizing transport in Armenia is a challenge, given that much of its road transport is fueled by natural gas imported at prices below international benchmarks. Transitioning away from fossil fuels and maximizing the potential of transport technologies required to achieve net zero would require more systematic and comprehensive transport sector planning, effective motorization management, and the expansion of charging infrastructure. Stricter emission standards for new and secondhand vehicle imports, regulatory requirements targeting the early electrification of company fleets and other high-use vehicles, and public financial support and regulations on electric vehicle charging infrastructure deployment would promote the adoption of electric and other low-emission vehicles, reducing overall energy demand thanks to the higher efficiency of these vehicles. Promoting a modal shift away from individual motorized transport, investing in a gradual rise of urban public transport and active mobility, and improving rail and logistics performance would help facilitate a sustainable and cost-efficient transition that addresses other transport-related externalities beyond emissions.

Investing an incremental $2.8 billion to scale up energy efficiency and electrification programs in the industry, building, and digital sectors could significantly reduce energy demand by 2040. Armenia has major unexploited energy efficiency potential, particularly in the building sector, which could pay for itself, reducing the overall cost of the energy transition to the economy. Strategic initiatives and reforms, including a governmental action plan on energy saving and renewable energy (RE), are already underway. But the residential energy efficiency and sustainable heating markets have been historically difficult to develop at scale, with limited financial resources available and low awareness of these. As a priority, developing and implementing a national program of energy efficiency in buildings would provide a foundation for the subsequent rollout to other sectors. Modeling done for this report suggests that energy efficiency measures in the building sector—such as improved thermal insulation standards of new buildings and extensive renovation of existing buildings—could cut final energy demand for heating and cooling by 2 and 36 percent by 2030 and 2040, respectively.

Policy priority 2 (adaptation): Boost agriculture productivity, food security, and resilience through water efficiency and conservation, early warning systems in agriculture, and strengthening critical infrastructure.

Investing around $1 billion in water efficiency, storage, and water resource management would support sustainability and growth in the agriculture sector. With access to water potentially declining at critical periods when demand is high, it will be increasingly important to manage competing needs, including for irrigation, energy (hydropower, cooling of nuclear and thermal generation), and industry (mining). In this context, more efficient water resource use—alongside more storage and macro-level management and planning—is vital. While the need for water storage is clear, a new masterplan would need to determine the location, size, and timing of new reservoirs. An ambitious adaptation portfolio that includes 15 new reservoirs (to increase total storage capacity by 7 percent) and investments to modernize and rehabilitate irrigation systems and increase efficiently irrigated land by 66 percent compared to the REF scenario would cost $1 billion (about 0.2 percent of GDP per year) and bring $2.6–3 billion in direct benefits, depending on the climate change scenario (figure S4). At the macro level, these investments would increase GDP by 0.5–1 percent per year after 2030, reducing the negative impact of climate change on GDP by 30 percent under the most severe scenario and completely reversing the impacts under more moderate scenarios.

Figure S4: Costs and benefits of adaptation portfolios across 55 climate change scenarios



Source: IEc analysis for this report
Note: Numbers are discounted with a 6% discount rate.

Policies and institutional reforms would strengthen water resource management and boost adaptation. The following priority actions will ensure sustainable resource management in a context of uncertainty about future climate change impacts and transboundary water availability:

- Allocating more resources to support hydrological, agrometeorological, climate, and meteorological monitoring using geographic information systems
- Providing incentives and trainings for farmers to use efficient irrigation systems
- Developing and implementing an adequate tariff methodology for water supply

- Undertaking a comprehensive re-evaluation of the volume of usable groundwater resources in the Ararat Artesian Basin, ensuring illegal water users (who mainly extract water for municipal and irrigation purposes) obtain water use permits, and revising water use permits based on the updated assessment of the volume of usable groundwater resources.

Investing $190 million to support a broad roll-out of CSA and early warning systems can play a key role in supporting strengthened climate adaptation while boosting economic growth, food security, and livelihoods for rural populations. Relatively few of Armenia's 300,000 farmers have awareness of CSA technologies and practices, despite substantial public funding (mostly subsidies) in the agricultural sector. Promoting innovation in climate-resilient crop production, energy and water-saving technologies, waste management, circularity, and regenerative agriculture will allow the country to respond to climate threats. Establishing a food security monitoring and early warning system and facilitating sustainable market linkages in the agrifood value chains through programs that support farmer integration and modernization, the widescale adoption of food quality and food safety standards, and value chain logistics will also help.

Targeted investments in the range of $790 million to improve the resilience of critical infrastructure, emergency service facilities, and land restoration could also bring significant positive economic and social returns. This can go a long way in reducing flood damages and losses. For example, this report estimates that investing $41 million in strengthening the resilience of schools and hospitals to severe flood risks can avoid losses to the budget worth two to four times the initial investment cost,[2] while investing $119 million to increase flood resilience on 13.6 km of primary roads, 3.8 km of secondary roads, and 75.8 km of tertiary roads would bring benefits worth up to 2.5 times the cost.[3] Investing $45 million would allow the country to rehabilitate, strengthen and/or rebuild 40 critical emergency response facilities (approximately 63 percent of available facilities) that are exposed to floods, earthquakes, and other major disasters. Finally, a land restoration portfolio investing $610 million across 5 percent of the country's total area would bring benefits four times higher by increasing crop production and reducing cultivation costs.[4]

Policy priority 3 (enabling reforms and institutions): Accelerate growth through fiscal and institutional reforms to support private sector transitions and protect the most vulnerable through social protection.

A resilient low-carbon transition will require $8 billion in additional adaptation and mitigation investments compared to the REF scenario by 2060, representing 2.5 percent of GDP per year, on average. This includes $2.4 billion by 2035 (1.8 percent of GDP per year) and 5.5 billion between 2035 and 2060 (2.6 percent of GDP per year). Many of these investments are to decarbonize the economy, particularly in the electricity and transport sectors (table S1). Although most can be privately funded, public investments will be required in the transport and water sectors, and to some extent, the residential and agriculture sectors.

[2] The only benefits included in these ratios are avoided flood damages. Other benefits include avoided learning loss in schools and avoided health services disruptions in hospital.

[3] The only benefits included are avoided flood damages. Additional benefits include avoided traffic disruptions and associated economic losses. A more ambitious scenario that targets all roads exposed to more than 10 centimeters of water would cover 125, 38, and 180 kilometers of primary, secondary, and tertiary roads, respectively, at a total cost of $183 million.

[4] Forest restoration would also increase ecosystem service supply and GHG emissions reductions. Even without accounting for the benefits of reducing GHG emissions, land restoration in Armenia is economically viable, with a benefit-cost ratio of 1.44.

Table S1: Investment needs of Armenia's resilient low-carbon pathway, compared to the reference scenario, until 2060

Sector	Net increase ($ billions, discounted) and average annual investments as share of GDP (%) between 2025-60	Estimated public/private split (%)*
Grand total	**8.0 (2.5%)**	**25/75**
Electricity	3.0 (0.9%)	7/93
Transport	0.2 (0.1%)	66/34**
Residential	1.5 (0.5%)	30/70
Industry and Other	1.3 (0.4%)	5/95
NZS total	**6.0 (1.9%)**	**16/84**
Water storage and irrigation efficiency	1.00 (0.32%)	80/20
Land restoration	0.61 (0.19%)	70/30
Resilient public infrastructure	0.18 (0.06%)	100/0
Agriculture	0.19 (0.06%)	10/90
Adaptation total	**2.0 (0.63%)**	**71/29**

Source: World Bank staff estimates, based on the modeling done for this report
Notes: Investments are discounted with a 6% discount rate. *Split is based on expert input, reflecting expectations for potential financial returns and Armenia's ability to mobilize private investment for these incremental investment categories, assuming that the policy recommendations of this CCDR are implemented. **Split refers to incremental investment in public and freight transport. The NZS foresees a net increase only in public and freight transport investment, and as the shift to public transport and 'avoid' strategies lead to lower overall demand, net private transport investment decreases. But in absolute terms, most of the transport investment is private.

Building on the country's strong track record of attracting private capital in the energy sector, Armenia could prioritize reforms to mobilize private capital for climate mitigation. Between 2007 and 2019, the World Bank estimates that 30 percent of all energy investments in Armenia (about $750 million) was public or publicly guaranteed (0.5 percent of GDP per year on average), while 70 percent (about $1,750 million) was private capital. For certain subsectors—such as onshore wind, solar PV, and hydro—the policy gap is small and may only require certain de-risking interventions, such as off-take guarantees, to mobilize private investments. In others, such as public transport and residential energy efficiency, policy support may have to include structural sector reforms to improve the level of commercialization, as well as financial support to close the residual viability gap. In a third category of subsectors, which includes energy storage, public support for demonstration and scale-up could help create the conditions for scalable private investment. Overall, when including private road transport and freight, discounted investment volumes in highly commercialized sectors add up to about $3.4 billion, or 48 percent of the total discounted investment needs until 2060 for mitigation.

Armenia's private sector also has a triple role to play in supporting adaptation by providing finance, adapting its own operations, and offering goods and services to help others adapt. This is particularly clear in the water sector. First, banks can collaborate with international financial institutions (IFIs) and the government to fund water efficiency, supported by international donors and blended finance. Investment mechanisms vary—and include private, public-private partnership (PPP), or public funding—depending on the purpose of the infrastructure. Second, the government can encourage companies to enhance their operations through time-bound, targeted subsidies or tax breaks. For large water users, this could include incentives to build reservoirs, upgrade water transport infrastructure to decrease water losses, and adopt efficient technologies; for small users, such as farmers, it could include incentives to implement drip irrigation or CSA. Finally, the widespread adoption of sustainable practices could foster a local market for related goods and services, with firms supplying farmers with locally produced and imported pipes, automated systems, and other equipment, as well as providing maintenance and training services. Armenia can use this opportunity to develop sectors such as PV-based irrigation and an Internet of Things for higher-efficiency and value-added agriculture.

A policy package that combines planning, fiscal policy, sectoral reforms and institutional reforms will be needed to incentivize the transition, mobilize the funds required for these investments, and ensure that vulnerable populations do not suffer from the transition.

Getting the prices right and protecting vulnerable households

Among other pricing instruments and environmental taxes, a carbon tax can play a pivotal role in supporting the achievement of climate commitments, incentivizing private investment, and generating revenues for public investment and to compensate vulnerable households. Introducing carbon pricing through a carbon tax is an effective way to spur the private investments needed to reach net zero emissions. Upstream carbon taxes can enable the taxation of the whole economy, including the informal sector, at low administrative cost, with few evasion opportunities due to physical infrastructure and emissions traces, reducing compliance costs and corruption opportunities. Recycling carbon tax revenues into targeted cash transfers can help offset losses and alleviate the impact of energy, transport, and other price increases on the poorest.

To afford the energy transition, lower-income households will need government support, especially for transport and heating services. In the simulations done for this report, using carbon tax revenues to compensate poor households could ensure low-carbon transition and energy prices have a minimal impact on poverty, increasing the poverty rate by 0.5 percentage points in 2030 compared to the REF scenario, and slightly reducing the poverty gap and inequality. More generally, to minimize poverty impacts and avoid negative impacts on vulnerable households, the government can accompany the transition with targeted social protection (SP) measures. Government support for building energy efficiency would also reduce the impact of decarbonization policies on the affordability of housing and business premises. Targeted government incentives could also promote electric mobility among lower-income groups.

Boosting private sector innovation and investments

Government reforms can help the private sector adapt and innovate in response to the global sustainability shift, which is key to a successful transition. Educating businesses on energy efficiency, promoting green audits, exploring the green market potential, and supporting labor mobility, up-skilling, education, and training will help ensure a workforce that is ready for the demands of the green economy. In the medium term, creating a supportive environment for innovative startups, investing in research and technology, and incentivizing green technology adoption are essential. Strengthening local supply chains, upgrading infrastructure to meet green standards, and expanding green financing will further Armenia's competitive edge in the green global economy.

Climate-focused PPPs can be used to leverage private investment in low-carbon and resilient infrastructure. Although PPPs allow for risk-sharing between public and private partners in critical sectors, without a strong institutional and legal framework, they can add fiscal risks and costs. And while Armenia has a legal PPP framework—based on a law adopted in 2019 and revised in 2021 (World Bank 2022c; CIVITTA 2022)—it needs a stronger institutional framework to mitigate fiscal risks and ensure effective risk-sharing. Armenia has PPPs in RE (Masrik-1 solar PV), water, and transport (South-Caucasian Railways and Armenia International Airports) but needs to increase institutional capacity, particularly in planning and project management to increase the predictability of project delivery (CIVITTA 2022).[5] Emphasizing climate resilience in PPP parameters, terms, and conditions, and attracting green financing are also crucial. Armenia is enhancing its PPP framework to better manage liabilities and maintain fiscal sustainability. For projects with high economic but low financial viability, the government might consider hybrid PPP models, which include viability gap funding to ensure feasibility.

[5] The Government of Armenia is exposed to around AMD256 billion in broad contingent liabilities from power purchase agreements (PPAs) in the energy sector and AMD87 billion in contingent liabilities from a PPP in the water sector. Total contingent liabilities from PPAs and PPPs are at 6.92% of GDP, with PPPs in the transport sector subject to significant material risk (contingent liabilities from South-Caucasian Railways and Armenia International Airports are 1.19% and 2.1% of GDP) (Schur, Manukyan and Melikyan 2023).

International debt financing will be needed to enable private investment at scale, and this has implications for project development and risk allocations. To date, financing for solar and hydropower projects has primarily come from international financiers (as sovereign or commercial financing), due to their ability to support larger-scale energy projects. This trend is expected to continue, with most financing for future projects likely to come from international banks and IFIs, in line with what is observed globally. But foreign direct investment in private external financing in general declined significantly in the decade to 2021, while access to domestic finance in Armenia is moderate and masks important disparities (World Bank forthcoming, a, 2024b; IMF 2023). Armenian banks are well positioned to provide at least a portion of the debt required for large projects at a cost-effective rate. But for projects to be bankable for this kind of debt financing, companies will need to adopt international best practices for project structuring, environmental and social risk management, and financial risk allocation.

Strengthening the institutional and policy environment

To deliver its climate commitments, Armenia needs to undertake a series of institutional and policy reforms. This includes adopting a national climate law;[6] ensuring a strong center-of-government approach to coordinate across policy documents and state agencies; reforming public finance management to leverage the potential of public investments; and ensuring a whole-of-economy approach to climate resilience and green transition. A series of sectoral reforms will also help it deliver on adaptation and decarbonization (table S2).

Transitioning to a green economy requires consistency and coordination across sectors, with the Ministry of Finance and Central Bank playing a central role. Coordinated sectoral and macroeconomic policies and actions that are consistent with the magnitude of existing and expected challenges are vital for achieving development objectives with financing and implementation capacity. Promising interventions include investing in key clean energy technologies with consistent cost declines, undertaking climate budget tagging and climate-informed budgeting, adopting a green taxonomy and sustainable finance framework, introducing central bank policies to reduce the value of polluting collateral, and enhancing climate-related financial risk disclosure.

Integrating a sector-by-sector understanding of climate risk, adaptation plans, and investment needs into the budget process will help accelerate adaptation investments. This includes improving data collection and processing systems, expanding and upgrading hydrometeorological observation networks, and strengthening data collection institutions. While Armenia has made progress with climate risk policies and institutional arrangements, undertaking a rigorous sector risk analysis and developing a risk management strategy that includes prioritized investments would be useful. Integrating this with the budget process and medium-term expenditure framework would help ensure fiscal sustainability.

Table S2 summarizes priority actions to remove key bottlenecks that slow down Armenia's resilient, low-carbon transition. A longer version of this table with a full list of recommendations, barriers to implementation, and institutions responsible for reform is available in chapter 5 of the full report.

[6] The Draft Law on Climate and the Draft Communication Strategy of the Inter-Agency Council on Climate Change, which have been circulated among stakeholders, and the government intends to adopt soon, address some policy gaps.

Table S2: High-level objectives and priority actions for removing key bottlenecks to climate action

High-level objective	Priority actions
Raise the ambition of the 2030 NDC mitigation target	• Raise the ambition level of the 2030 NDC target to at least 65% lower than 1990 to put the country on track for its 2050 target
Promote green growth through structural reforms	• Analyze the potential of green products and services for export • Extend market energy audits • Design and implement reforms to promote labor mobility, upskilling, education, and training for the green economy
Design appropriate pricing instruments and compensation	• Design pricing policies, consider introducing an explicit carbon price through an upstream carbon tax and by scaling up existing fossil fuel excises, and use carbon tax revenues to compensate vulnerable households • Consider targeted use of feebates to provide incentives for firms to adopt emissions-saving technologies
Enable private capital mobilization	• Strengthen institutional capacity to implement PPPs by improving the PPP framework to better monitor and manage contingent liabilities, maintain fiscal sustainability, and ease implementation; scale up wind, solar, storage, and other clean energy projects that can be supported through standardized mechanisms • Follow up on the 2023 Sustainable Finance Roadmap and adopt a sustainable finance framework that is aligned with EU regulation • Adopt a green taxonomy, an environmental, social and governance disclosure framework for financial and nonfinancial companies, and a standard for issuing thematic corporate and sovereign bonds • Work with local banks, international donors, and IFIs to create concessional credit lines for private investment in adaptation
Scale up variable RE generation, accompanied by enabling investments in the transmission grid and storage	• Develop and implement a national transmission grid modernization program and strengthen incentives for private distribution grid investments to absorb over 1 GW of variable RE integration by 2030, and 4 GW by 2040 • Pilot and scale up battery solutions in the grid and at building level to achieve at least 1.8 GW of battery storage by 2030 to increase shares of solar PV
Invest in publicly funded infrastructure and strengthen policy frameworks for clean transport	• Roll out charging infrastructure and review short-term tax incentives for electric mobility to achieve 42,000 electric vehicles as passenger cars by 2030, potentially supported by revenue-generating interventions, such as carbon-differentiated vehicle taxation • Raise fuel efficiency and local pollutant emission standards for vehicles and provide incentives for replacing old vehicles • Consider introducing fuel efficiency standards for second-hand vehicle imports (carbon dioxide per kilometer), differentiated by vehicle segments
Continue the transition to competitive energy markets, while providing targeted protection of vulnerable consumers	• Continue the gradual liberalization of the electricity market • Introduce a gradual but steady increase in end-consumer natural gas prices to international benchmarks to incentivize the shift from natural gas to electricity • Identify energy-vulnerable consumers and pursue targeted SP measures in parallel to price reforms, alongside a broader strengthening of the SP system, including data, capacity, and targeting
Develop programs to scale up energy efficiency and electrification in the industry, commerce, buildings, and digital sectors	• Set up a national program for building energy efficiency with public and private finance mobilization
Increase water storage and efficiency	• Rehabilitate and modernize water conveyance infrastructure, on-farm systems, and pumping stations serving at least 50,000 hectares of irrigated land • Design a masterplan for new storage investments
Improve water resource management	• Allocate more resources to support hydrological, agrometeorological, climate, and meteorological monitoring using geographic information systems and remote sensing tools • Carry out a comprehensive re-evaluation of the volume of usable groundwater resources in the Ararat Artesian Basin, ensure illegal water users in the basin obtain permits, and revise the permitting and fines system • Strengthen the institutional capacities of the Water Committee, the Water Supply Agency, and water user associations, and create more favorable enabling environments to improve efficiency and implement environmental and rural development policies • Develop and implement an adequate tariff methodology for water supply systems and irrigation; review and update existing (outdated) irrigation norms; and bring in metering to transition to a two-part irrigation tariff based on area and volumes
Increase agricultural productivity and resilience with CSA	• Record CSA activities in the 2024 agriculture census

High-level objective	Priority actions
	• Provide incentives and training for farmers' use of drip irrigation and CSA practices • Bring the early warning system in agriculture to full functionality
Improve food system integration, competitiveness, and resilience	• Set up a food security monitoring and early warning system to enable prompt responses to economic, climate, and other shocks
Increase the resilience of infrastructure systems	• Develop an overarching, comprehensive, and proactive approach for identifying and managing critical infrastructure risks • Identify the critical roads and bridges that are exposed to natural hazards
Develop land restoration programs	• Develop a landscape restoration approach as an element of a broader framework for the national adaptation plan • Repurpose harmful agricultural subsidies into incentives for landscape restoration initiatives and by introducing payments for ecosystem services • Include forestry and landscape restoration as an activity for green taxonomy

1. Development and Climate in Armenia

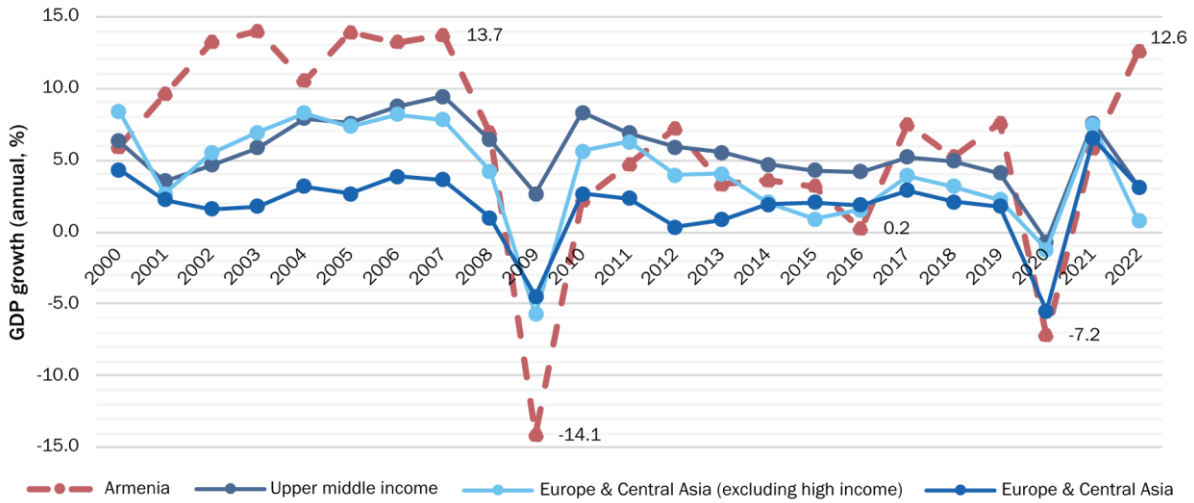
MAIN MESSAGES

- Armenia has experienced robust growth and structural transformation. But resource and market dependence, combined with high levels of poverty and lack of access to good jobs, means the economy and households are highly vulnerable to shocks.
- Armenia could experience large losses from climate change, environmental and natural disasters, with important poverty, macroeconomic and fiscal impacts.
- Growth has been generated with high energy intensity, air pollution, and environmental degradation, creating vulnerabilities to the global green transition.

1.1. Development context: a need for new growth drivers to reduce volatility and create quality jobs

Armenia's economic growth has been strong but volatile, reflecting high vulnerability to external shocks. Gross domestic product (GDP) growth averaged 6.3 percent over 2000–23, advancing the country to upper-middle-income status. This was particularly strong between 2000 and 2008, expanding 11 percent annually. But with growth fueled by a rapid influx of foreign direct investment and remittances, and exports benefiting from the commodity price boom, the country was vulnerable to external shocks. It experienced one of the sharpest contractions in Europe and Central Asia during the 2008–09 global financial crisis, and recovery was slowed by the oil price shock in 2014 and global sanctions on Russia, its largest investor and main export market, from 2015. In 2020, the country once again experienced one of the sharpest contractions in Europe and Central Asia, with GDP falling 7.2 percent (figure 1), as effects of the COVID-19 pandemic were exacerbated by the impacts of military conflict with Azerbaijan. This reversed in 2022, as the relocation of large numbers of companies and nonresidents to Armenia following Russia's invasion of Ukraine fueled double-digit (12.6 percent) growth—the highest in the region—followed by 8.7 percent growth in 2023.

Figure 1: Armenia's economic growth pattern



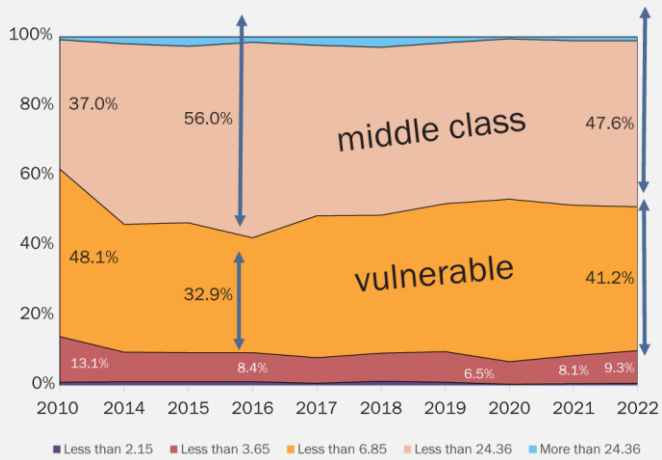
Source: World Bank staff calculations, based on https://data.worldbank.org/indicator/NY.GDP.MKTP.KD.ZG (2000–21 data) and the Statistical Committee of the Republic of Armenia, ARMSTAT (2023 data)

Growth volatility is partly a function of a resource-dependent economic base with high levels of export product and market concentration. Armenia's economy is on the path of structural transformation, as the share of services in GDP rose from 46 to 59 percent, and the share of agriculture fell from 18 to 8 percent, between 2012 and 2023. Yet agriculture still accounts for 22 percent of employment. The sector is characterized by low productivity and, while highly diversified overall, exports are highly concentrated, with cognac, wine, and tobacco products accounting for half of all agriculture exports. The industrial sector is highly dependent on mineral resources,[7] with metal concentrates, gold ore, ferromolybdenum, and processed aluminum accounting for 40 percent of exports in 2020 (OEC 2023). The bulk of mining exports are in unprocessed products, and therefore exposed to fluctuations in global commodity prices. Exports are also concentrated to a narrow range of markets—for example, 43 percent of exports in 2022–23 went to Russia—exposing Armenia to rising market risks. But while diversifying its export market could help reduce exposure, Armenia would need to improve environmental standards in the mining sector and introduce renewable energy to enhance access to markets in Europe and elsewhere, particularly in light of the European Union's (EU) implementation of the Carbon Border Adjustment Mechanism (CBAM) (see section 1.3). Armenia's economy is also highly dependent on food and energy imports. Its import dependency ratio for food is 0.43 (FAO and World Bank 2023), and 100 percent (mainly from Russia) for natural gas, which represents 63 percent of the country's primary energy supply and is widely used for power generation, heating, and transport (World Bank 2024b).

In the absence of structural reforms, Armenia faces stagnating long-term growth. Despite robust GDP performance in recent years, the World Bank's Long-Term Growth Model[8] projects Armenia's baseline growth rate to slow to an annual rate of 2 percent over the next 25–30 years, driven by decelerating total factor productivity growth, a 0.5 percent slowdown in population growth, and diminishing returns on investment.

Armenia's economic model has not created enough jobs, giving rise to relatively high unemployment, poverty, and vulnerability, and contributing to continued high levels of outmigration. Despite achieving a steady reduction in poverty since 2010, the incidence of poverty is still higher than expected, given the country's level of income, and progress has stalled in recent years. And with over 40 percent of the population vulnerable to falling into poverty, the share of population that is either poor or vulnerable was higher in 2022 than in 2016 (figure 2). High levels of vulnerability are associated with weak labor market conditions, and Armenia has one of Europe and Central Asia's highest unemployment rates, averaging around 18 percent over 2008–20. Although the most recent period of growth pushed unemployment down to 12.6 percent in

Figure 2. Share of population that is vulnerable



Source: World Bank staff calculations, based on ARMSTAT 2023 and international poverty threshold data
Note: Poverty is not strictly comparable before and after 2019 due to a revision in the Integrated Living Conditions Survey questionnaire and data collection methods.

[7] Mainly known for its copper, molybdenum, and gold resources, Armenia also has deposits low- grade iron ore. There is potential to find deposits of nickel, cobalt, platinum, palladium, and rare earths, but this would require many years of exploration and investment. Potential for lithium is not considered significant.

[8] https://www.worldbank.org/en/research/brief/LTGM.

2023, the lack of opportunities for good jobs and high poverty levels continues to contribute to high rates of outmigration, dampening growth potential and furthering the cycle of remittance reliance. High levels of vulnerability also amplify the impacts of exposure to external shocks, as poor and unemployed populations have fewer resources to bounce back with after income and asset losses following a shock.

Large spatial disparities, along with associated fragility risks, increase the vulnerability of Armenia's households and its economy overall. There is high variation in welfare across the country: poverty is highest in rural areas and secondary cities, and the gap between the capital, Yerevan, and its surrounding communities has risen in recent years. The spatial gap in welfare and access to opportunities correlates with a strong regional and rural-urban divide in terms of access to roads, schools, and health facilities. Poverty—especially rural poverty—is particularly high in border regions, and two of its four borders (with Türkiye and Azerbaijan) have been closed for years. Conflict with Azerbaijan has raised risks not only in border regions but across the whole economy, impacting the agriculture, tourism, and other sectors, and hitting both investor confidence and household sentiment.

Despite historical growth challenges and persistent vulnerabilities, global integration and continuing structural transformation presents opportunities for greener, more productive, and more sustainable growth. The country's long-term vision, articulated in the *Armenia Transformation Strategy 2050*, foresees a path to sustainable job creation and rising real wages through investment in a knowledge-based, innovative, and green economy. The ongoing shift toward more knowledge-intensive, higher-productivity sectors is illustrated by the success of the information technology services sector, which accounted for $1.1 billion in exports in 2023. There are also opportunities to shift to greener and more value-added activities within traditional resource-based sectors. For example, reducing the energy, water, and environmental footprint of mining could allow Armenia to grow the sector and take advantage of a rapidly rising global demand for copper in the low-carbon transition, while investing in climate-smart agriculture (CSA) and developing high-value horticulture and other value chains offers potential for diversifying exports while supporting rural economies and enhancing domestic food security. All these opportunities can be facilitated by regional and global market integration, including through the Comprehensive and Enhanced Partnership Agreement (CEPA) with the EU and broader regional and global market opportunities enabled by investments in the Middle Corridor—a freight transport corridor linking China to Western Europe through Central Asia and the South Caucasus— and the prospects of implementing the "Crossroads of Peace, initiative by the Government of Armenia.

1.2. Climate change context: impacts on natural capital, growth, and poverty

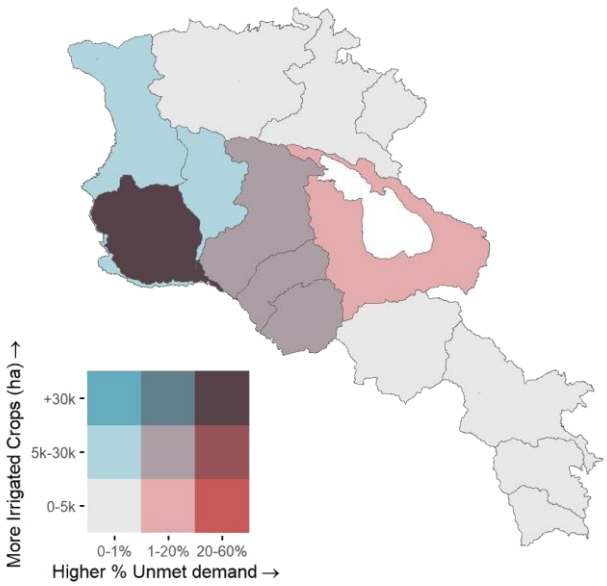
Armenia's natural capital—notably its agriculture, forests, and water—plays a key role in the country's economy, long-term development, and poverty reduction. Natural capital accounted for close to 11 percent of Armenia's wealth in 2018; nearly three times the European and Central Asian average (World Bank 2021). Its natural capital consists mainly of cropland and pasture, which account for three-quarters of the country's natural capital, followed by protected areas (16 percent), forests (13 percent) and metals and minerals (6 percent, but copper, gold and ferroalloys are also the biggest export earners). The main strategic commodities are grains (wheat and barley) and legumes, but agriculture production is highly diversified. Despite the economy's structural change toward services, the agriculture sector remains important for the economy and employment: 61 percent of rural households have agricultural incomes and a 22 percent of the employed work in agriculture. The water sector is essential for agriculture (with half of arable land irrigated), energy production (hydropower), and metals and mineral production (which make up more than a third of all exports).

Armenia's use of natural capital is unsustainable. The country faces a high level of water stress, with a withdrawal-to-supply ratio of 57.8 percent, according to AQUEDUCT (Hofste et al. 2019). Agriculture is by far the largest water user, accounting for 70 percent of total consumption. Deforestation is also

an issue, with more than 6,000 hectares lost between 1990 and 2020 (FAO 2020), and nearly 70 percent of the country's 0.33 million hectares of forest suffer from some degree of degradation (World Bank 2023b). Deforestation and forest degradation are driven by anthropogenic and natural factors, including overharvesting for fuelwood and timber, illegal logging, uncontrolled grazing, infrastructure development, mining, water extraction for irrigation, pests and diseases, salinization, and increased forest fires due to frequent droughts, particularly in the Ararat valley and some areas of Vayots Dzor and Syunik provinces or *marzes* (Shulte and Harutyunyan 2020). Climate change enhances both types of factors, accelerating the rates of deforestation and degradation.

The most significant physical impacts from climate change in Armenia are likely to result from changing precipitation patterns, which will impact rainfed crop production and increase water stress for irrigation and hydropower production. The analysis carried out for this Country Climate and Development Report (CCDR) uses six climate scenarios to represent the uncertainty pertaining to future climate change impacts: three dry/hot scenarios corresponding to global climate models that predict high increase in temperature and reductions in precipitation; and three wet/warm scenarios corresponding to global climate models that predict lower increase in temperature and an increase in precipitation. While levels of precipitation vary significantly under alternative climate change scenarios, under all scenarios, precipitation increases in the winter (especially in the wet/warm scenarios) and decreases in the summer (especially in the dry/hot scenarios). This has significant implications for rainfed crop yields. The seasonality of runoff also changes compared to a reference scenario without climate change (REF scenario), increasing in late winter/early spring under all scenarios, and reducing in summer under dry/hot scenarios. Changing runoff patterns could increase hydropower production by 10 percent by 2050 under the wet/warm scenarios or decrease it by 10 percent under the dry/hot scenarios. By contrast, water availability for irrigation could be impacted much more strongly and negatively, with unmet water demand for irrigation expected to increase in several basins across the country. Metsamor and Hrazdan Basins—two of the three responsible for over 70 percent of national irrigation—face increased unmet demand under all climate scenarios (figure 3).

Figure 3. Current hectares of irrigated crops and future unmet demand for irrigation under a dry/hot scenario



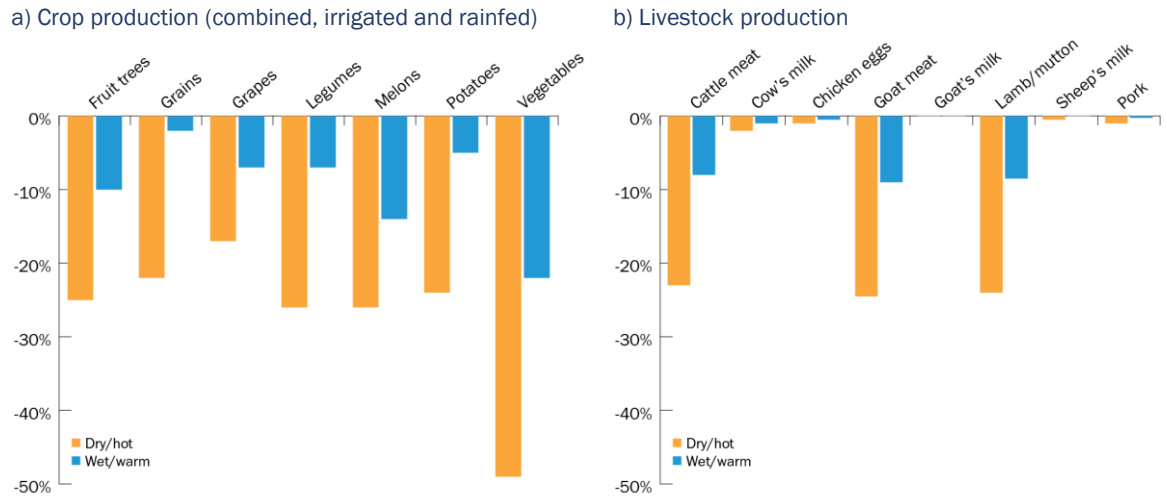
Source: World Bank staff calculations, based on analysis from Industrial Economics (IEc)
Note: The subnational areas in this map represent the country's water basins used in the model.

These impacts of human activity and climate change on the availability of Armenian water are compounded by the impacts on transboundary waters in neighboring countries. Around 30–35 percent of Armenia's surface water flows originate from neighboring countries (FAO 2022) and both local and transboundary water flows have reduced, potentially due to regional climate changes and intensified human activities in upstream countries (World Bank 2022b). For example, upstream activities on the Araks River in Türkiye and Iran—including dam construction and water diversion for irrigation and hydropower generation—can impact water availability, agricultural practices, and overall water security in Armenia, Azerbaijan, and Iran, which all use the river to support agriculture, industry,

and communities. Similarly, the construction of upstream dams and reservoirs on the Vorotan River, especially in Azerbaijan, could affect water availability downstream in Armenia.

In the absence of adaptation, crops and animal production could be strongly affected by climate change. Both irrigated and rainfed crops are expected to see significant declines in yields through 2050 as a result of changes in temperature (for fruit and vegetables) and precipitation (for most other crops), and reduced water availability for irrigation. A dry/hot future will be more damaging for rainfed crops, with a 37 percent decline in yields (against 25 percent for irrigated crops) while a wet/warm future will be more damaging for irrigated crops, with a 12 percent decline (against 8 percent for rainfed). Increased erosion due to precipitation is expected to decrease crop yields by an additional 1 percent under a wet/warm future. The impacts of climate change on yield varies by crop, with vegetable production hit hardest under both scenarios and grape production least impacted; but almost all assessed crops are projected to experience yield loss of 20 percent or more in a dry/hot future (figure 4a). Cattle, goat, and sheep production will also be highly affected, with yields falling by more than 20 percent in a dry/hot future and by around 9 percent in a wet/warm future (figure 4b).

Figure 4: Projected average climate change impact on production in Armenia (2041–50)



Source: IEc (2024)

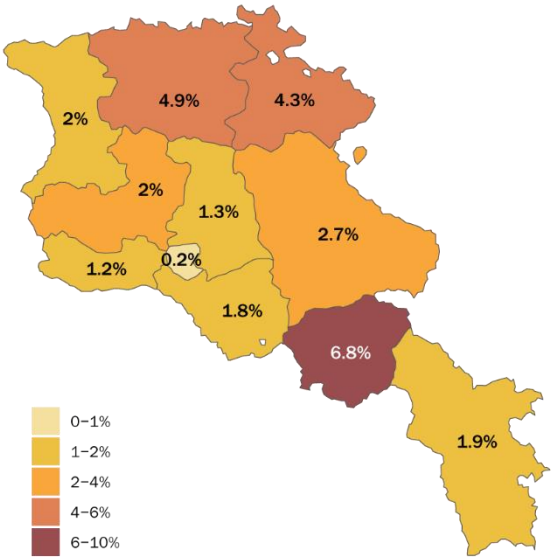
Agricultural output and wider ecosystem services will be hit further as climate change accelerates the impacts of landscape degradation. This will have profound implications for livelihoods and diminish essential ecosystem services, such as food, wood, water, and soil fertility, increasing the risk of poverty. In 2010, more than 14 percent of the rural population relied on degraded land, and this share has risen each year (UNCCD 2017). Land degradation is expected to worsen in the future, as climate impacts interact with other hazards—such as vegetation degradation, landslides, and decline in biomass productivity—alongside changes in rural population density. Future land degradation risks vary across the country, with hotspots located in provinces (marzes) with high agriculture production (the northwest and center) and high poverty (the north and the Ararat Valley). Without action, nearly 0.2 million hectares of additional pastureland and 0.05 million hectares of cropland will be degraded, and the severity of degradation will increase. This will significantly reduce agricultural yields, leading to production losses of $363 million (close to 1.9 percent of GDP), more than double the current impacts of degradation. By 2050, land degradation will also reduce the returns of forest ecosystem services by $17 million, while increasing the costs related to greenhouse gas (GHG) emissions by $43 million, and infrastructure, by $14 million.

Heat could also affect human capital, especially in the agriculture sector. The impact of heat on labor productivity is projected to increase over time under all climate scenarios and in all sectors by 2050. Although this will have relatively low impacts, in the agriculture sector, it could result in a 1 percent labor productivity loss under the dry/hot scenario. This only captures the impact of average temperature increase, and heatwaves could have larger health impacts, especially in cities when compounded by air pollution. Research shows that cardiovascular mortality, and to a lesser extent, respiratory mortality, increase during heatwaves on high pollution days (Analitis et al. 2014). This would exacerbate an already high prevalence of noncommunicable diseases in Armenia.

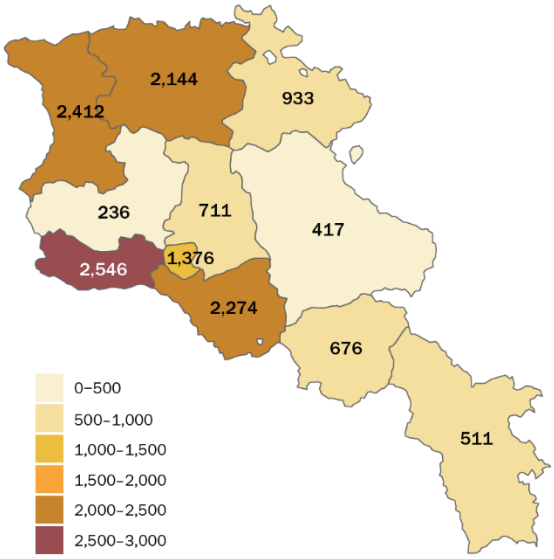
These impacts are compounded by Armenia's high exposure to natural disasters, with large spatial variation. The country is exposed to frequent floods, droughts, hail, and landslides. Over the past 25 years, climate-related events have caused more than $1.5 billion in assessed damages and losses, around 0.6 percent of GDP in average annual damage and losses. Armenia also lies in a region of a high seismicity and earthquakes: with more than 2.5 million people in 48 cities located in seismically active areas, it is estimated that a 250-year earthquake would cost more than 80 percent of the country's GDP (World Bank 2016). A multihazard exposure index that considers and gives equal weight to the relative risks of exposure to landslides, earthquakes, floods, drought, forest loss, air pollution, precipitation variation, and temperature variation identifies areas in the north, west (including the capital Yerevan), and south as most highly exposed to natural hazards. But regions in the east and central areas also face relatively high exposure to floods, droughts, and earthquakes.

Figure 5: Flood asset risk and population vulnerability, by marz

a) Average annual flood losses, 2020



b) Number of people exposed to floods who live in dilapidated houses



Source: World Bank staff assessment, based on Fathom flood maps and ARMSTAT 2023

Floods already impact Armenia's assets and this could get worse in some marzes under climate change. An assessment of flood impacts on roads, buildings (including schools and hospitals), and agricultural land finds that, on average, floods could cost Armenia 0.8–2.3 percent of GDP annually in asset damages (Lenoble and Rozenberg 2024).[9] The primary cost drivers are damage to roads, followed by buildings, with costs unevenly distributed over the territory (figure 5a). Relative to regional GDP, the most flood-exposed marzes are Vayots Dzor, Tavush, Lori, and Gegharkunik in the northeast. Damage to schools and hospitals are highest in the northeastern marzes of Lori and Tavush and the

[9] The uncertainty is mostly driven by the data used to value the assets.

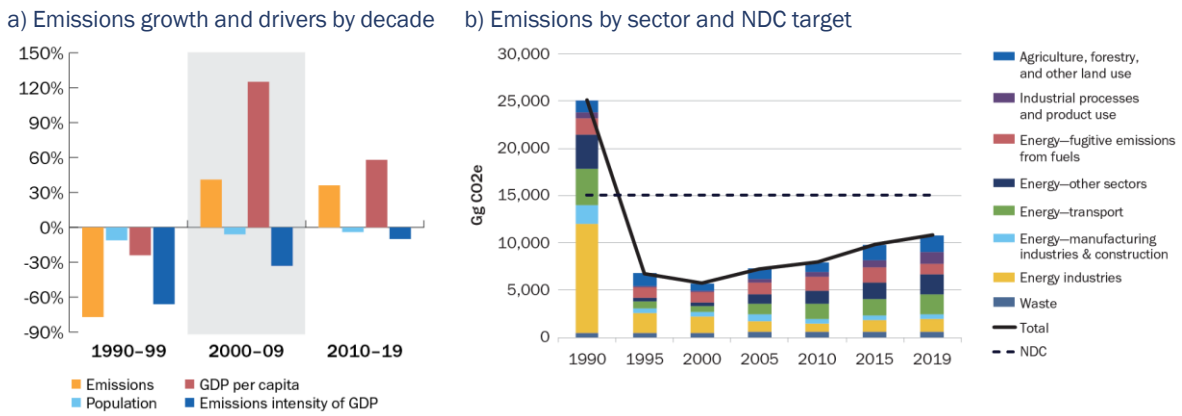
southern marzes of Vayots Dzor and Syunik. Under a medium climate change scenario, reduced river flows could lead to a decrease in fluvial flood damage, while intensified precipitation could increase pluvial floods. This could decrease flood risks in the Ararat valley (Ararat, Armavir, and Yerevan) and an increase flood risks in every other marz.

Direct flood damages impose a significant cost on some households. The poverty rate in Armavir, Shirak, and Tavush marzes is higher than the national average, and flood losses would have high socioeconomic impacts. Nationally, 39 percent of the poorest households (bottom 10 percent) live in dilapidated homes, which are more vulnerable to flood risks, with a higher number in Ararat, Armavir, Lori, and Shirak marzes (figure 5b). If the country could avoid flood losses in homes, 3 percent of households would save an average of $3,200 annually. In Yerevan, these losses represent 8 percent of the annual value of housing; in Lori and Tavush, 21 percent. Avoiding flood losses on homes would lift almost 1,500 people out of poverty. Flood impacts on agriculture would cost exposed households 5.2 percent of their consumption at national level on average, ranging from 0.7 percent in Yerevan to 8 percent in Armavir and 10 percent in Shirak. By avoiding flood losses on agriculture land, 7,700 households would avoid income losses of AMD 2.1 million ($4,875) every year, lifting 1,300 people out of poverty.

1.3. Climate policy context: risks and opportunities from the global energy transition

Although Armenia is a low GHG emitter in global terms, emissions are rising and out of line with global pathways and long-term domestic commitments. With a population of less than 3 million, Armenia contributes less than 0.02 percent of annual global GHG emissions. At 10.78 million tonnes of carbon dioxide equivalent (MtCO2e) in 2019 according to official data—or 3.8 tonnes of carbon dioxide equivalent (tCO2e) per capita—its annual GHG emissions remain far below the 1990 baseline, driven by economic shock and rapid structural change in the decade following the break-up of the Soviet Union, when much of Armenia's heavy industry, including huge rubber and other chemicals factories, shut down (figure 6). Since 2000, emissions have been rising at an average 3.2 percent per year, with the economy's emissions intensity continuing to decline at an increasingly moderate pace. So, while Armenia is in line to meet its nationally determined contribution (NDC) commitments, which are anchored to the 1990 baseline, the trajectory of emissions growth is out of step with longer-term decarbonization objectives.

Figure 6: GHG emissions in Armenia, 1990–2019



Source: Government of Armenia National Inventory

The energy sector drives GHG emissions and is the largest contributor to Armenia's methane emissions, with fugitive emissions and transport standing out as major contributors. Around two-thirds of GHG emissions in Armenia come from the energy sector. Primary energy consumption is dominated

by natural gas, while electricity generation is distributed between natural gas, hydropower, and nuclear. Emissions from the power sector are expected to have risen since 2020, with the installation of a large new thermal power plant and projected increasing power demand. Emissions from the agriculture, forestry, and other land use, and industrial processes and product use (IPPU) sectors have also been rising, driven by shrinking forest carbon sinks for the former. In contrast with regional and global emissions profiles, fugitive emissions and the transport sector (which is heavily reliant on natural gas) are responsible for a large share of Armenia's overall emissions, contributing 10 and 20 percent, respectively. Methane emissions account for around 22 percent of Armenia's GHG emissions, with more than 40 percent coming from the energy sector, including transport, and the remainder from agriculture and waste.

Armenia's economy remains energy-intensive, contributing to acute environmental problems, including air pollution and deforestation. Although it ranks 119th of 198 countries in terms of GHG emissions per capita, it ranks 95th in emission intensity of GDP,[10] due to low value-added, a concentration of energy-intensive sectors, such as mining, and the emissions intensity of its transport[11] and heating systems. The high emissions intensity of the country's GDP contributes to air pollution, which is a growing environmental problem (box 1), with the annual cost of the damage to health from fine particulate matter (PM2.5) pollution reaching 10.6 percent of GDP (World Bank 2023b). Land degradation is significantly aggravated by high rates of deforestation (70 percent of Armenia's forests are degraded), driven by mining, illegal logging, and the rural population's high reliance on firewood for heating.

In view of the country's high dependence on energy imports from Russia, the transition to domestic renewable energy (RE) brings opportunities for Armenia to strengthen energy security. With imported gas providing 63 percent of the country's total energy supply—one of the largest shares in the world—and imported oil providing 16 percent, Armenia imports natural gas and oil for about four-fifths of its overall energy needs, mostly from Russia. Despite its relatively diversified mix of thermal, hydropower, nuclear, and solar power Armenia relies on imported fuels to generate around 70 percent of its electricity. All of its thermal generation relies on gas, and in 2021, almost 88 percent[12] of its gas and all of its nuclear fuel came from Russia. Energy security risks provide a clear incentive for Armenia to develop its own domestic renewable resources. But it imports gas at a low cost (around $180 per 1,000 standard cubic meters, which is substantially below international gas price benchmarks). As a result, there are economic incentives to maintain natural gas as the dominant fuel in the economy, at least in the short term.

Energy poverty is a long-standing challenge for Armenia's households, underscoring the importance of managing energy price shocks. Households in Armenia already spend an average of 16 percent of their income on energy, and rural households, up to 20 percent. One of the highest figures in Europe and Central Asia, this is well above the affordability threshold of 5–10 percent. Survey data suggest that more than 40 percent of Armenia's population cannot afford to heat their homes properly,[13] and World Bank estimates suggest that the last major pricing reform in 2017 disproportionally affected the poorest 20 percent and single elderly households. In the context of the global and domestic energy transition, managing price impacts on the poor will be vital.

[10] https://www.climatewatchdata.org/countries/ARM?end_year=2020&start_year=1990.
[11] Transport accounted for around 30% of all energy-related CO2 emissions in 2019 (Armenia National Inventory).
[12] https://www.iea.org/reports/armenia-energy-profile/overview.
[13] https://armstat.am/file/article/poverty_2023_en_2.pdf

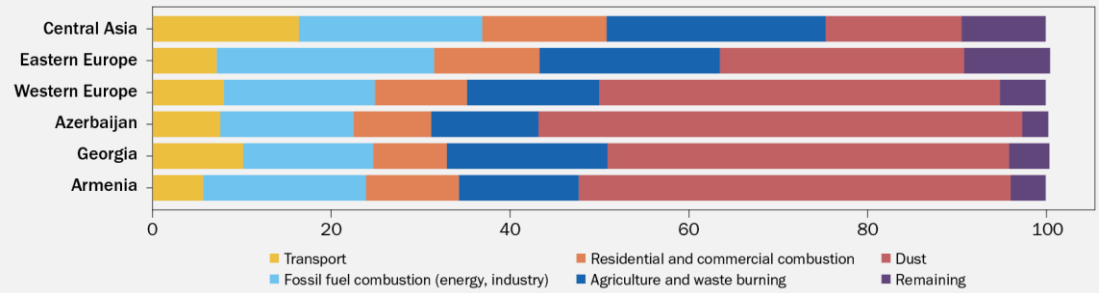
Box 1: Air pollution: a critical concern in Armenia

Air pollution significantly impacts multiple dimensions of welfare, including mortality, morbidity, mental health, cognitive ability, and productivity. In a recent public opinion survey, 63 percent of respondents identified air pollution as a top environmental concern in the country (UK Government 2022). Along with deforestation, air pollution was by far the most-cited concern. Armenia ranks as the world's 31st most polluted country in terms of average PM2.5 concentrations between 2018 and 2023.[a] A recent World Bank study shows that PM2.5 pollution in Armenia was responsible for more than 3,000 deaths and cost 10.6 percent of GDP in 2019, compared to the EU average of 3.8 percent (World Bank 2022a). These high health impacts partly derive from indoor air pollution, which is the result of heavy fuelwood use for heat and cooking in rural areas (box 4); but ambient air pollution also contributes.

There are various sources of ambient air pollution (figure B1.1) with around half coming from dust (including from soils), in line with other countries in the immediate region, and a function of the landscape and climate. Fossil fuel combustion in the energy and industry sectors is a smaller contributor to air pollution than in comparator countries, while emissions from transport, agriculture, and waste burning are comparatively high. According to satellite imagery, dust is concentrated mostly in the south and northeast, while PM2.5 is high in Yerevan, the northeast and the south (figure B1.2).

The government has made significant progress in policies to improve air quality, with major amendments and additions to the 1994 Law on Protection of Atmospheric Air. But multiple bylaws have yet to be amended and outdated standards for emitted pollutants and agglomerations need to be revised. Significant gaps also remain in the country's air quality monitoring capacity, with equipment dating from 1970s incapable of measuring key pollutants and providing real-time monitoring of air quality data. This prevents authorities from alerting residents in areas where there are pollution spikes, which would enable them to take precautionary measures.

Figure B1.1: PM2.5 concentration contributions by source across select countries and regions

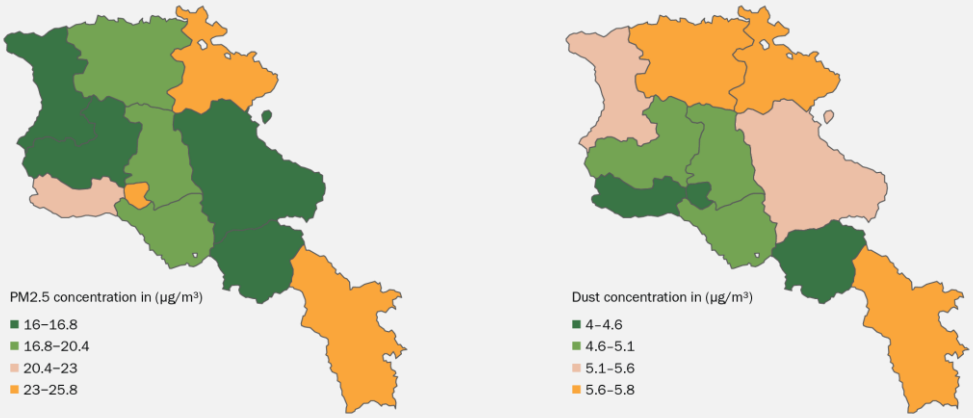


Source: Simpson et al. 2012

Figure B1.2: Spatial distribution of dust and PM2.5 pollution in Armenia

a) PM2.5 concentration

b) Dust concentration

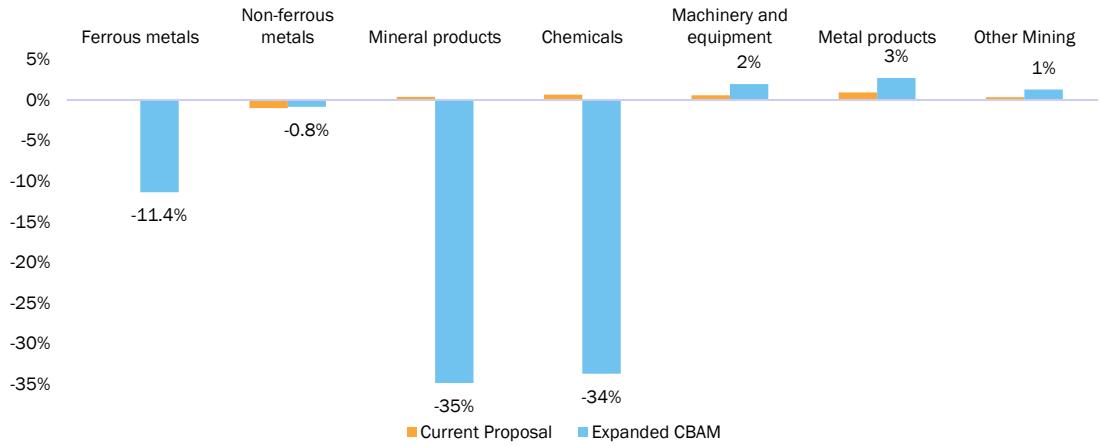


Source: Simpson et al. 2012
Note: Calculated from a 0.1° x 0.1 ° grid.

a) https://www.iqair.com/us/world-most-polluted-countries.

In the absence of action on mitigation, Armenia's energy-intensive export sectors face transition risks from the EU CBAM. Expected to become operational by 2026, the CBAM will act like an import tariff, imposing product-level taxes on imports to the EU based on product emissions intensities. Armenia faces few risks in the short term: under the first phase, nearly all of Armenia's ferrous metals exports (ferroalloys) are exempt, and most mineral and chemical products are not covered. Modeling[14] indicates that CBAM may even create opportunities for downstream sectors that use inputs from CBAM sectors—such as machinery and equipment or metal products—since Armenia's manufacturers would not face CBAM costs on their inputs, while EU producers will. As a nonferrous metal, aluminum would be Armenia's the most impacted commodity in the first phase, but only constitutes 2 percent of total exports in 2020 (World Bank forthcoming, a). If the EU were to extend its current CBAM proposal to all chemicals, all nonferrous metals, petroleum and coal production, extraction of asphalt bitumen and iron ore, and glass, as is being discussed for Phase 2, Armenia's exports of ferrous metals to the EU could drop by over 11 percent, and mineral products and chemicals exports by nearly 35 percent (figure 7).

Figure 7: Armenia's projected exports to the EU in 2035, by CBAM sectors (deviation from baseline)



Source: World Bank staff analysis, based on ENVISAGE computable general equilibrium (CGE) model

At the same time, the global low-carbon transition will create opportunities for Armenia to expand the export of green goods and diversify the economy. Increased global demand for climate-critical minerals—particularly copper and possibly nickel, cobalt, and other minerals—represents a significant opportunity to expand Armenia's mining sector. To take advantage of this opportunity, the country will need to substantially step up exploration,[15] implement reforms to reduce the sector's emissions intensity, and transform operating practices to reduce water contamination, as set out in its 2023 Strategy for Development of the Mining Sector. And while Armenia's manufacturing is GHG-intensive in the ferrous and nonferrous metal sectors, it compares favorably to regional and global competitors in other manufacturing sectors, such as apparel, which has high job creation potential, and could open up opportunities for Armenia to establish a competitive advantage in markets that value green sourcing. Exports of environmental goods remain small, but have grown rapidly, reaching $12.7 million in 2022, driven mainly by RE products.

[14] Using the Global CGE model ENVISAGE (v.10) based on GTAP 10 Power database, covering 2014–35, where 2014 is the base year, and considering the current CBAM proposal and potential expansion of CBAM scope.

[15] Since 2010, the average amount of minerals needed per new unit of power generation capacity has increased globally by 50% as the share of renewables in new investment has risen. The world's demand for copper will reach 53 million tonnes annually by mid-century, more than double the current global mine production (S&P Global 2022). The demand for other minerals with potential in Armenia—such as nickel, and cobalt—will also increase exponentially.

2. Climate commitments, policies, and capacities

MAIN MESSAGES

- Armenia has strengthened its climate commitments with an ambitious NDC and a commitment to climate neutrality by 2050. It has also developed a comprehensive set of policies and strategies to support mitigation, strengthen adaptation, and increase resilience.
- Reforming institutions and policies—including a national climate law, a strong center-of-government approach to coordinate across policy documents and state agencies, public finance management, to leverage the potential of public investments, and a whole-of-economy approach to climate resilience and green transition—would help it deliver these commitments.
- Armenia's private sector is investing significantly in climate-related projects, but several constraints limit its growth, including a perceived lack of policy coordination and incentives, an absence of mechanisms to assess climate risks, inadequate access to finance and markets, and a need to modernize public infrastructure.

2.1. Armenia's major commitments and policies on climate change

Armenia's climate policy framework has been on a steady trajectory of growth and increased commitment. It ratified the United Nations Framework Convention on Climate Change (UNFCCC) in May 1993, the Kyoto Protocol in December 2002, and the Doha Amendment to the Kyoto Protocol and the Paris Agreement in February 2017. By ratifying the Paris Agreement, the country's intended nationally determined contribution, established in 2015, became its NDC for 2015–20. It adopted an updated and strengthened NDC in 2021,[16] setting an economywide target to reduce GHG emissions by 40 percent below 1990 levels in 2030. According to the 2021–26 Action Plan of the Government of Armenia,[17] the government plans to update the NDC for a new ten-year (2025–35) implementation period by November 2025.

Armenia's NDC commitment is underpinned by the Long-term Low Greenhouse Gas Emissions Development Strategy (LT-LEDS), adopted in December 2023.[18] Laying out its commitment to climate neutrality and reaffirming the government's ambition to reduce GHGs to 2.07 tCO2e per capita by 2050,[19] the LT-LEDS covers five sectors: energy, agriculture, industrial processes, forestry and other land use, and waste. It pursues technological progression and sustainable development across sectors, while realizing the potential for reducing GHG emissions. **The government has indicated that it will pursue policy and regulatory reform, with a particular focus on the energy sector, to achieve its 2030 and 2050 objectives.** For example, the Energy Sector Development Strategic Program aims to increase the share of solar energy generation in the country's generation mix to at least 15 percent by 2030. [20] To ensure implementation across other sectors, the government has adopted a series of strategic policies as decrees and amendments to existing laws, as outlined in Table 1.

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[16] Republic of Armenia. Government Decision N 610 – L of 22 April 2021, Nationally Determined Contribution 2021–2030 of the Republic of Armenia to Paris Agreement. Available online: https://unfccc.int/sites/default/files/NDC/2022-06/NDC%20of%20Republic%20of%20Armenia%20%202021-2030.pdf.

[17] https://www.gov.am/files/docs/4740.pdf.

[18] Republic of Armenia. Government Decision N 2318-L of 28 December 2023, Long-Term Low Greenhouse Gas Emission Development Strategy of the Republic of Armenia (until 2050): https://unfccc.int/sites/default/files/resource/UNDP%20LT_LEDS_ARMENIA.pdf.

[19] Climate neutrality refers to achieving net zero by balancing GHG emissions so they equal (or less than) the emissions that get removed through the planet's natural absorption (UNFCCC 2021).

[20] https://energyagency.am/public/uploads/news/pdf/EnergyStrategy_angleren.pdf?fbclid=IwAR3Yf9Vbt2UVcJrqvmD_Y9heyktnvJ-ydSPQa5tCrhNe6iLVWZCBKgIJ3Do.

Table 1: Key strategic policies and legislation to support climate commitments

Regulatory act or law	Law no.	Year	Summary
Strategic Program of Perspective Development, 2014–2025	N 442-L	2014	Outlines actions to maximize the use of domestic energy resources, focusing on RE and promoting energy efficiency.
RA 2021–26 Government Program	N 1363-A	2021	Emphasizes the development of nuclear energy, RE sources, introducing energy-efficient and new technologies to ensure energy security, providing affordable and reliable energy supply, mitigating and preventing climate change-related problems pursuant to commitments under international agreements, and developing and implementing a sustainable policy to promote a green economy and achieve long-term sustainable development goals.
Action Plan of the Government Program 2021–26	N 1902-L N 2117-L	2021 2022	
EU-Armenia Comprehensive and Enhanced Partnership Agreement Roadmap	N 666-L	2019	Sets out 12 climate change and 34 energy efficiency, RE, and energy security actions to address Armenia's obligations under the CEPA, signed in 2017, which emphasizes the importance of strengthening multilateral cooperation to further develop and implement the UNFCCC and related agreements and decisions, including the Paris Agreement.
Strategic Program for the Development of the Energy Sector of RA (until 2040)	N 48-L	2021	Safeguards national energy security priorities based on nuclear energy, modern gas-fired power plants, and the development and expansion of economically viable and technically available RE sources, mostly solar. Armenia is developing solar energy capacity toward 1,000 megawatts by 2030 to increase its green energy share to at least 15% of the power generation mix and improve the country's energy security.
2022–2030 National Energy Efficiency and Renewable Energy Program and List of Measures for Phase 1 (2022–24)	N 398-L	2022	Defines new sectoral targets for 2022–24 in the following strategic areas: developing RE capacities, energy saving, promoting electricity use, further localizing the Sustainable Development Goals, and planning the next phases of program implementation for 2022–30.
Amendments to the RA Energy Law		2014	Aims to create favorable conditions for RE sources by extending the power purchasing agreement from RE sources (except for small hydropower plants) from 15 to 20 years.
		2016, 2017	Promotes solar energy generation for own needs, with peak capacity of up to 500 kilowatts (inclusive) by stipulating that such power plants generation can be carried out without the activity licenses issued by the Public Services Regulatory Commission.
Amendments to the RA Law on Energy Saving and Renewable Energy		2016	Stipulates mandatory compliance with technical requirements in new residential apartment buildings, as well as in assets constructed, rebuilt, or repaired at the expense of state funds.
		2017	Adopts net metering for electricity production by autonomous producers using solar energy, stipulating that final billing between an owner of a solar photovoltaic (PV) station and the grid is based on the whole-year difference of generated and consumed amounts of electricity.
		2018	Stipulates that products bought to meet the needs of the state must meet established energy efficiency requirements.
The RA Law on Making Addendum to the RA Tax Code		2019	Fully exempts the import and sale of electric vehicles from value-added tax (VAT) from July 2019 to January 2026.
Strategy of the Main Directions Ensuring Economic Development in Agricultural Sector of RA for 2020-2030 Action Plan for 2023-2026	N1886- L N1222- L	2019 2023	Envisages improving nitrogen fertilizer management and organic farming development, the sustainable intensification of animal breeding through improved species and breeds, an improved irrigation system, the promotion of digital agriculture, and technological innovation.
Solid Waste Management System Development Strategy for 2021–23	N464-L	2021	Envisages, among other things, reducing methane emissions by improving the solid waste management system.
Kigali amendment of the Montreal Protocol on Substances that Deplete the Ozone Layer		2019	Imposes a ban, from 2033, on importing hydrofluorocarbons from countries that are not Parties to the Kigali Amendment, as well as their export to and transit transfer in these countries.

Armenia is one of few countries in the region that has adopted and made progress on implementing a national adaptation plan (NAP). Its NDC recognizes the critical importance of climate adaptation to achieve its social and economic development goals. In 2021, the government approved the National Action Program of Adaptation to Climate Change and the List of Measures for 2021–25,[21] which marked the coordinated launch and implementation of a NAP process in Armenia. The NAP action plan identifies seven sectors with particular adaptation needs and envisages the development of sectoral adaptation plans (SAPs) for forest ecosystems, human health, water, agriculture, energy, human settlements and infrastructure, and tourism, and outlines adaptation plans for all 10 marzes. The water SAP has been adopted and the forest and transport SAPs are under development; regional plans have been developed for Shirak and Tavush, and plans for Syunik and Gegharukunik are under development. According to the 2021–26 Action Plan of the Government of Armenia, it should adopt a new national action program of adaptation to climate change and list of measures for 2026–30 by December 2025.

Alongside key climate-specific policies, the EU-Armenia CEPA plays a crucial role in driving the reform agenda with a strong focus on decarbonization, adaptation, and resilience. The 2021 CEPA agreement provides a framework based on four key pillars: better living standards, cleaner environment, fairer and safer society, and more choice for education. CEPA is one of the key bilateral agreements that has been most extensively nationalized by the government, through the 2021–26 Government Action Plan and the CEPA implementation roadmap, which outlines 12 specific climate actions as part of an extensive set of environmental commitments. These include measures to phase out ozone-depleting substances and fluorinated GHGs, establishing a GHG inventory and monitoring, reporting and verification systems, with corresponding institutional capacity, and developing the climate change adaptation concept and a national program of actions in line with climate change mitigation. By early 2024, most of these actions has been completed or were near completion.

2.2. Institutional framework for climate change action

While Armenia's overall climate policy framework is adequate, there are several gaps to address to ensure effective implementation. The draft action plan for implementing the NDC[22] identifies these gaps as: securing a solid climate policy framework; providing information and baseline data; building institutional capacity and strengthening institutional coordination; incorporating climate considerations into sectoral development plans; adopting a plan to mobilize investment to achieve the NDCs and NAP; and adopting a sustainable financing framework.

Armenia lacks streamlined institutional arrangements for developing, implementing, and assessing the impacts of climate policies. As the government's commitments are best implemented in cooperation with development partners, they can have differing views in terms of what to prioritize first. Without a national climate policy framework that sets out the hierarchy and interrelationships of climate policy documents, the scope of responsibilities, development and implementation criteria, and monitoring and evaluation systems, there can be disruptions and contradictions in strategic planning.

The Ministry of Environment has already developed a national climate law, the draft of which is in circulation and is slated for adoption soon. This law would create a much-needed normative basis for implementing mitigation and adaptation-related policies and regulations, helping ensure accountability, enforcement, and oversight of the climate commitments.

[21] Republic of Armenia Government Decision N 749-L of 13 May 2021, Framework National Strategy on Adaptation to Climate Change Impacts for 2021-2030 and the list of measures for 2021-2025. Available online: https://unfccc.int/sites/default/files/resource/NAP_Armenia.pdf.

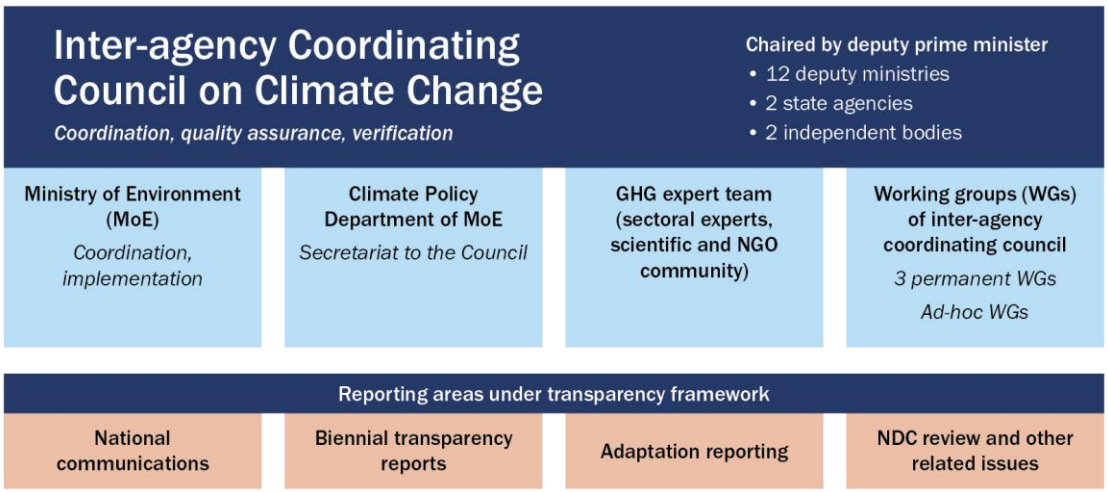
[22] https://eu4climate.eu/download/draft-government-decree-on-approving-the-action-plan-financing-strategy-and-investment-plan-for-implementation-of-ndc-of-armenia-2021-2030-under-the-paris-agreement/.

The lack of quality baseline data on socioeconomic development raises challenges for designing interventions and could pose risks for meeting targets. Climate policy development should be based on available, accurate, reliable, and clear information. Indeed, the Paris Agreement established a new transparency framework under which countries are obliged to report on their progress in reducing GHG emissions and increasing resilience to climate change. With insufficient baseline data, it is difficult to implement key measures, such as establishing a national monitoring, reporting, and verification system.

2.2.1. Institutional capacity and coordination

Although the institutional arrangements for supporting the climate agenda are in place, there is a need for clearer mandates and clearer scope—particularly for interinstitutional coordination—and stronger technical capacity. The Ministry of Environment is responsible for developing and implementing the national policy on climate change, but has limited mandate for engaging in other ministries' climate-relevant programs. The government established the Interagency Coordinating Council in 2012 to coordinate climate change considerations in sectoral strategies and policies, and to monitor the implementation and validation of reports to the UNFCCC. To strengthen the council's effectiveness, the government initiated a series of reforms in 2021, including elevating the chair to deputy prime minister level, creating working groups (figure 8), and expanding its scope. But the council continues to have limited effectiveness, with infrequent meetings, a lack of strategic context, and no mandate for implementation. The government is considering further reforms to strengthen civil society participation, would need to complement these with further actions to ensure greater involvement of the Ministry of Finance, a more systematic center-of-government approach, and stronger alignment between sectoral strategies and a whole-of-government climate action plan, incorporated into cyclical government action plans. Being more systematic about leveraging technical capacities built through cooperation with development partners would help build a robust set of effective institutional, structural, entity and functional level capacities in climate-related ministries and functions.[23]

Figure 8: Interagency Coordinating Council on Climate Change institutional framework



Source: Presentation by the Ministry of Environment at UNESCAP meeting in 2023, https://www.unescap.org/sites/default/d8files/event-documents/1-1.3%20Nona_Budoyan%20Climate%20Action%20in%20Armenia_0.pdf.

2.2.2. Sectoral integration of climate agenda

Although the government outlines its development vision in its 2021–26 Program and Action Plan, the link to climate transitions is not well defined. Neither the Green Economy Strategy nor the Circular Economy Concept Note, which would provide important framing for sectoral-level climate policy and

[23] The Draft Law on Climate and the Draft Communication Strategy of the Inter-Agency Council on Climate Change, which have been circulated among stakeholders, and the government intends to adopt soon, address some policy gaps.

investments, have been finalized, despite being slated for adoption by the end of 2022 and 2023, respectively. This is largely due to the government's decisions to halt the adoption of strategies and concept notes unless they are reflected in the state budget and to have larger sectoral strategies, which would make implementation and oversight more manageable.

Although there have been increasing efforts to develop sectoral adaptation and mitigation strategies, concerns remain over the degree to which sectoral strategies are being executed. Two important sectoral strategies—the 2023–33 road strategy[24] and the National Forest Policy, Strategy and Action Plan[25]—have been developed and are pending approval. But the adoption of these and other sectoral strategies and policies has been delayed as the government attempts to improve oversight and evaluation of their implementation, noting, for example, that few of the SAP priority measures are reflected in the medium-term expenditure framework, and sectoral strategies do not always properly incorporate climate objectives and commitments. As a result, the government is considering incorporating climate strategies into larger sectoral strategies and budget planning. For example, although the agriculture SAP was developed following the NAP, government decided to incorporate it into the Action Plan for the Implementation of the Agricultural Sector Strategy 2023–26, although key measures from the SAP were not included in the final sector strategy. The government is now planning a Transport Road Sector Strategy for Armenia through 2045, with a climate adaptation component.

2.2.3. Public financing for climate

Armenia has yet to adopt a strategy for financing its NDC and NAP commitments. Although it developed an NDC Action Plan, Financing Strategy and Investment Plan, the government has yet to adopt it, focusing instead on finalizing and adopting the LT-LEDS. The document estimates the funding requirement for primary mitigation actions at more than $1.5 billion and envisages a mix of financing sources, including state budget, international financial institutions (IFIs), the private sector, and green financing instruments, such as bonds, equity investments, and swaps. The NAP Action Plan does not envisage developing a financing strategy or identify specific funding needs for adaptation.[26]

While Armenia is increasingly financing climate-related expenditures from domestic resources, funding levels remain low. Armenia conducted a Climate Public Expenditure and Institutional Review (CPEIR) in 2020 which revealed that, while climate-related expenditures are increasingly funded from domestic sources, between 2017 and 2019, only around 3.2 percent of the state budget was related to climate, on average. More than half of all climate expenditure during this period focused on adaptation, and just over a third on mitigation. The other investments support both adaptation and mitigation. Since the government does not have a functioning climate budget tagging mechanism, it is unclear how these figures have evolved since the CPEIR was conducted.

Reforming the public finance management framework will make it more climate-inclusive and responsive. This includes developing a climate budget tagging or related mechanism, developing climate change-related performance indicators, increasing parliamentary scrutiny of public expenditure on climate, considering climate impacts when prioritizing investments and programs, and enhancing the capacity of ministries to identify climate-relevant expenditures (UNDP 2020).

[24] https://www.e-draft.am/projects/4990/justification.

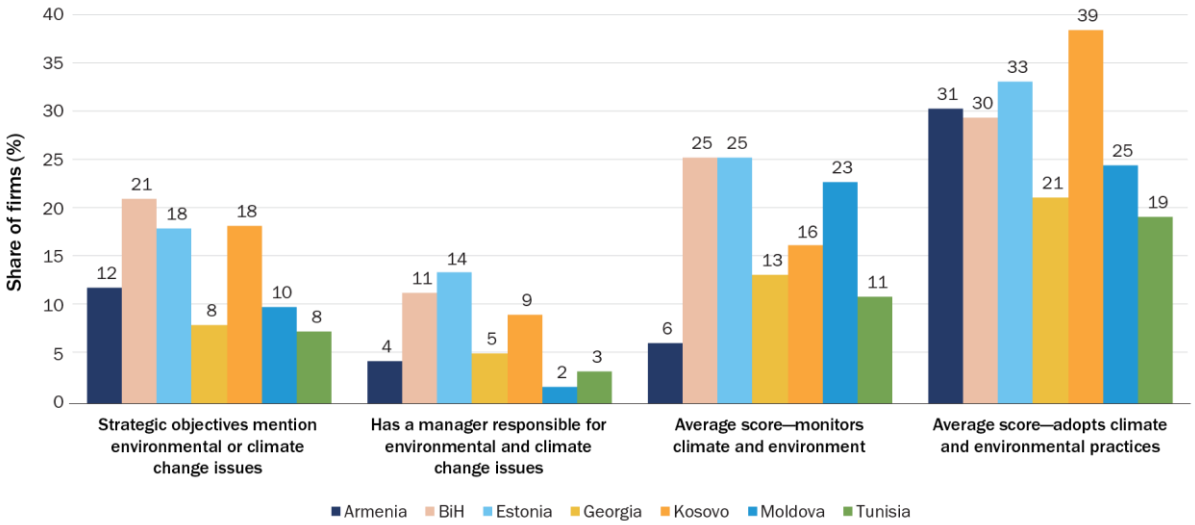
[25] https://www.e-draft.am/projects/5673.

[26] An initial assessment of adaptation needs in OECD (2021) finds that, of total mitigation and adaptation investment needs for 2020–30, amounting to approximately $5.7 billion, 86% are for mitigation. Adaptation investments amount to only $202 million, and crosscutting measures to around $779 million. The report identifies that a lack of baseline data for adaptation needs, inclusive of agriculture and disaster risk reduction, resulted in the approximation of potential needs, which could differ from the country's actual adaptation and resilience needs.

2.3. Engaging the private sector

Armenia's private sector is showing interest in climate-related investments, but this is likely driven by operational constraints rather than awareness of climate-related risks and opportunities. A small sample survey of 16 organizations covering the agribusiness, consulting, energy, finance, hospitality, manufacturing, metal processing, research and education, telecommunications, and water sectors developed for this CCDR found that almost 70 percent of firms had made climate-related investments in the last three years, mostly in energy efficiency and solar PV generation. Results from the 2019 Business Environment and Enterprise Performance Survey find that around 30 percent of Armenian firms have adopted practices or made investments that are related to climate or the environment (figure 9), which is on a par with regional peer countries. But these investments may be driven less by climate awareness than by the need to compensate for infrastructure deficits. The latest available World Bank Enterprise Survey (World Bank 2020b) finds that 62.7 percent of Armenian firms experience electrical outages, and 11.2 percent water insufficiency, which is significantly higher than European and Central Asian average, at 27.8 and 3.1 percent, respectively. Monitoring of climate and environmental outcomes is lower among Armenian firms (6 percent) than in peer countries (up to a quarter), and they focus less strategic and human capital on the climate agenda (figure 9). But, despite limited awareness of and capacity on climate and environmental issues, and the lack of government 'push'—for example, through regulatory requirements or incentives—the private sector is ready to invest in climate and environmental practices for efficiency gains and in response to market signals.

Figure 9: Share of firms reporting selected climate and environmental practices



Source: World Bank and EBRD 2019
Notes: Figure shows average share of firms reporting that they monitor energy consumption, water consumption, and carbon dioxide (CO2) emissions; and that have adopted heating and cooling improvements, more climate-friendly energy generation, machinery and equipment upgrades, energy management, waste minimization, recycling, waste management, vehicle upgrades, improved lighting systems, other pollution control measures, and energy efficiency enhancements.

Armenia can leverage increased private sector investment in green value chains and productivity-enhancing strategies across the whole economy. Among the factors driving private investment in green start-ups and value chains, investors highlight the importance of market size, which is a limiting factor for Armenia, availability of skilled labor, accessibility of suppliers, connectivity concerns, energy costs, policy environment, infrastructure quality, and the technology and innovation ecosystem (World Bank forthcoming, b). The industry can also play a significant role in promoting energy efficiency, with a recent study in the region showing that greening the private sector has a pro-competitiveness effect (World Bank Group 2023). Using obsolete energy-intensive technologies impacts firms' competitiveness, which, given the pass-through from energy intensity to emissions, can contribute to Armenia's climate

transition path. As adverse climate and energy shocks associated with geopolitical tensions become more frequent, greening the private sector is likely to be the most important source of private sector resilience in coming years (World Bank Group 2023).

Armenia's private sector has pointed to weaknesses in the policy and financing environment that are holding back climate investments. Results from a private sector workshop focused on climate change-related challenges and opportunities around energy, agriculture, water, and finance identified the following barriers to unlocking private sector climate investment:

- **Limited incentives from the policy environment,** including a lack of both energy efficiency and construction standards and appropriate water management regulation, as well as a need for better market regulation to ensure fair competition, and to improve access to green finance, especially for small companies
- **A lack of policy coordination across public institutions** in the financial sector and the real economy constrain the development of the regulatory framework needed to incentivize investment
- **A lack of openly available methodologies, tools, and human capital for assessing climate risks and the environmental impacts of their operations,** which would help firms to better monitor their operations and identify financing risks and opportunities
- **Limited access to technologies to support climate adaptation and energy efficiency,** particularly in energy and agriculture sectors, through limited access to supply chains or finance
- **A need to modernize public infrastructure** that is outdated (such as water) or could be supported by investments in RE, transport, and green construction.

2.4. Leveraging citizen engagement to mobilize sustained climate action

Armenian citizens are concerned about climate change but lack significant awareness of the issues. Several recent surveys of citizen perceptions of climate change in Armenia (UNICEF 2022; UK Government 2022; Leiserowitz et al. 2022) find varying levels of awareness and concern over climate change, with differences between the youth and older generations. But results from a global survey of 160 countries (Leiserowitz et al. 2022) indicates that, while Armenian citizens are only slightly below the European average in terms of seeing climate change as a threat, they are second-lowest (after Kosovo) in terms of self-reported awareness about climate change, with just 37 percent saying they have a lot or moderate knowledge about climate change, compared, for example, to 92 percent in Finland. They also have the second-lowest share of citizens who believe climate change is mostly caused by human action; this is also true for how regularly they report hearing about climate change, which may explain their perceptions.

Citizen concerns over wider environmental challenges can be leveraged to support stronger climate action. While the public perception is that climate challenges are an agenda of interest for a narrow scope of stakeholders, and citizens are not convinced that the climate should be a major government priority, climate surveys consistently show high levels of awareness and concern over related environmental degradation—notably, air pollution and deforestation. Combined with the global survey finding that Armenians were relatively well-disposed to participating in an organized group to respond to climate and environmental issues, this suggests that there may be opportunities to leverage citizen engagement on climate, particularly through environmental issues that impact their daily lives. In this context, it is important to ensure that the groups that are likely to be disproportionately impacted, further marginalized, displaced, or impoverished as a result of climate change, or face barriers to engagement, are included in discussions on climate action.

3. Policies and investments to address climate and development challenges in key sectors

MAIN MESSAGES

- While Armenia is on track to achieve its 2030 NDC target, increasing its near-term ambition and rapidly accelerating policy implementation will be crucial for achieving its 2050 emission target of no more than 2.07 tC02e per capita by 2050.
- Energy modeling suggests that Armenia could fully decarbonize by transitioning from a natural gas-based to a solar-powered economy, electrifying transport and residential energy, and scaling up energy efficiency.
- Increasing the efficiency of water conveyance and on-farm irrigation and supporting farmers to adopt climate-smart techniques are priorities for adaptation. In the medium term, it may also be necessary to increase water storage and expand irrigation.

3.1. Net zero pathways for the energy system

An energy system-wide[27] modeling analysis was carried out for this CCDR to assess sectoral decarbonization pathways for Armenia's economy.[28] Three main scenarios were modeled to assess specific policy choices, representing least-cost pathways to reach specified climate goals under different resource constraints, fossil fuel prices, and technology cost assumptions (box 2). GDP growth and the economic structure in all scenarios are aligned with the REF scenario of the macroeconomic modeling presented in chapter 4. All assumptions related to global fossil fuel prices should be understood as scenarios rather than projections. Agriculture, waste, and land use, land use change, and forestry are omitted from the scenario modeling, but assumed trends for these sources of emissions are included in the presented estimates of overall emissions.

Key output variables of the model include sectoral emissions, annualized energy system costs, and investment. All variables are calculated with a breakdown by sector and technology. *System costs* are the total of capital expenditure (CAPEX) and operating expenditure (OPEX). The difference between the CAPEX component of the system costs and investment is that *CAPEX* represents the annualized cost of the capital stock, while *investment* is the one-off outflow related to newly acquired or installed assets in the year of commissioning. *System costs* represent the most appropriate measure for total cost of energy, while *annual investment* is an indicator of annual capital mobilization requirement.

Box 2: Scenarios for the quantitative energy system analysis

The **reference (REF) scenario** reflects the continuation of the current trends of Armenia's energy system until 2060 and includes policies adopted by 2021 and projects that are already in the pipeline. This scenario serves as a baseline to assess and quantify the incremental effects of the decarbonization scenarios described below. Petroleum prices assumed in this scenario are derived from the IEA's Stated Policies Scenario,[a] with adjustments to reflect fuel transportation costs to Armenia. Gas prices are assumed to remain constant in real terms as in 2020, reflecting an assumption that Armenia continues to rely on piped gas priced through long-term contracts. Solar

[27] The *energy system* is understood here to encompass energy production and all major energy-consuming sectors, including transport, residential buildings, industry, and the commercial sector.

[28] The analysis used the CompactPRIMES model, a partial market equilibrium model that assesses the impacts of energy and climate change mitigation policies. The analysis estimated projected energy-related GHG emissions—that is, fuel combustion—and emissions from IPPU. Fugitive emissions from the oil and gas sector were analyzed separately and integrated ex-post into the analysis.

and wind resources are taken from the World Bank's Global Solar Atlas[b] and Global Wind Atlas,[c] respectively. Hydropower production profiles reflect mean SSP3–7.0 climate impacts,[d] reflecting high global emissions.

The REF with international gas prices (REF-IGP) scenario is a variation to the REF scenario that reflects the full economic opportunity cost of gas, assuming international gas prices plus transport cost to Armenia, rather than maintaining current gas price arrangements. This scenario serves to investigate the impact of energy security trade-offs and economic incentives for Armenia to decarbonize.

The **announced policies scenario (APS)** projects Armenia's energy system metrics based on a specific outlook by 2060, assuming the achievement of national strategic targets and pledges, including the NDC and sectoral strategies in energy, transport, and housing. For example, in the energy sector, the APS assumes achievement of all targets outlined in the LT-LEDS and the 2040 Energy Sector Development Strategy. Under the APS, Armenia reduces GHG emissions by 40 percent compared to 1990 levels by 2030 and limits emissions to no more than 2.07 tCO2e per capita by 2050. The APS adopts the additional sectoral and economywide policies required to achieve these climate pledges. Assumed petroleum prices are derived from the IEA's Announced Pledges Scenario[e], with adjustments to reflect fuel transportation costs to Armenia. Gas price and wind and solar resource assumptions are the same as in the REF scenario. Hydropower production profiles reflect mean SSP2–4.5 climate impacts—that is, moderate global emissions.

The **net zero emissions scenario (NZS)** aims to approximate net zero GHG emissions in the broader energy sector, including energy-related and IPPU emissions, by 2060. The main mechanism for achieving decarbonization in this model is carbon price serving as a proxy for any form of economically efficient decarbonization policy, accompanied by a gradual phase-out of underpricing of natural gas, the adoption of vehicle emission standards in the transport sector, and the provision of subsidies for energy efficiency in the tertiary and residential sectors. Assumed petroleum prices are derived from the IEA's Net Zero by 2050 Scenario,[f] with adjustments to reflect fuel transportation costs to Armenia. Gas price and solar and wind resource assumptions remain as in the REF scenario, and hydropower production reflects current trends—that is, limited physical climate impacts.

Three variations of the NZS are presented to illustrate the potential impacts of constraints that Armenia may be subject to. These are:

- The **solar land-use restriction (SLR) scenario,** which imposes an additional restriction on land use for solar PV, by excluding all land with any (including partial) agricultural use to illustrate potential impacts of land-use competition between food and solar PV development. The NZS only excludes irrigated cropland and land with forest cover.
- The **no-nuclear scenario (NNS),** in which Armenia does not replace its nuclear power plant and all installed nuclear generation capacity is decommissioned by 2036.

The **higher biomethane blending (HBB) scenario**, which models a world where synthetic methane is less readily available, increasing biomethane blending in the gas grid from 19 to 30 percent to meet piped gas demand. This is broadly in line with the potential reported for Armenia.

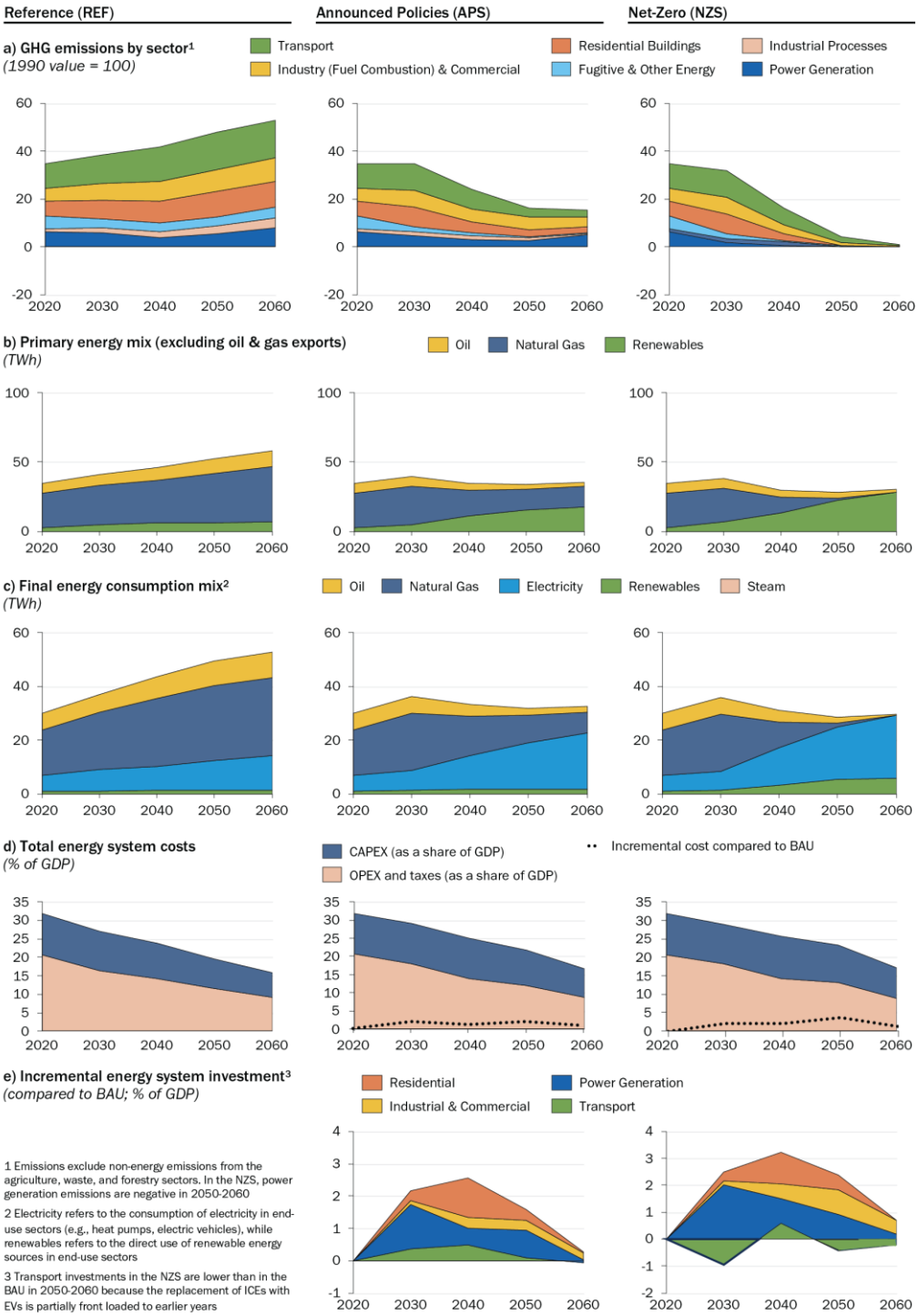
[a] https://www.iea.org/reports/global-energy-and-climate-model/stated-policies-scenario-steps.
[b] https://globalsolaratlas.info/map.
[c] https://globalwindatlas.info/en.
[d] See IPCC (2021) for an introduction and definition of *shared socio-economic pathways* or *SSPs*.
[e] https://www.iea.org/reports/global-energy-and-climate-model/stated-policies-scenario-steps
[f] https://iea.org/reports/global-energy-and-climate-model/net-zero-emissions-by-2050-scenario-nze

3.1.1. Armenia is on track to achieve its 2030 NDC target but miss the 2050 per-capita emissions target announced in the NDC for 2050

By implementing the policies introduced so far in this report, Armenia would achieve its 2030 NDC target (-40 percent compared to 1990) but not its 2050 target of no more than 2.07 tCO2e per capita. Under the REF scenario, Armenia's energy-related and IPPU GHG emissions would continue to rise compared to 2020 but remain 62 percent lower than 1990 levels in 2030, exceeding the NDC target of 40 percent, and 52 percent lower in 2050. Under this scenario, Armenia's energy mix would remain

essentially unchanged, with final energy consumption dominated by natural gas and electricity generation consisting of a relatively stable mix of nuclear, natural gas, and renewables. RE would experience continued growth but remain only 12 percent of total primary energy supply in 2060, almost doubling compared to 2020 levels. However, under REF scenario policy conditions, GHG emissions would reach about 3.94 tCO2e emissions per capita from the energy system alone, not accounting for other emissions sources, and the country would miss its long-term mitigation target of 2.07 tCO2e per capita by 2050, announced in the NDC. Figure 10 summarizes the trends in emissions under the REF scenario, APS, and NZS, as well as other key results.

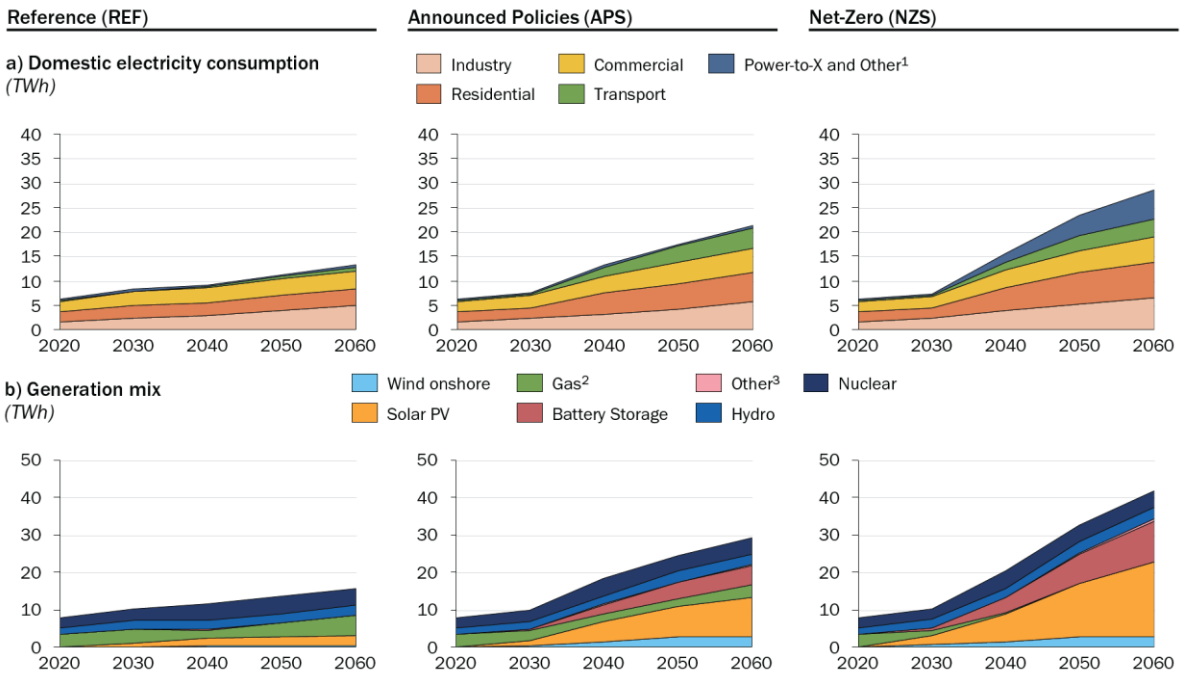
Figure 10: Systemwide indicators across the REF, APS, and NZS scenarios



3.1.2. Additional mitigation efforts are necessary to achieve the 2050 NDC target under the Announced Policy Scenario

The APS has a substantially more ambitious decarbonization trajectory than the REF scenario, even in the near-term, with net emissions from the energy system peaking in 2025 (4 percent above 2020 levels) and falling thereafter. Under the APS, energy- and IPPU-related emissions are projected to fall up to 85 percent by 2060 compared to 1990. By 2030, emissions are expected to fall to 7.9 MtCO2e (about 65 percent lower than 1990 levels); and by 2050, to 3.7 MtCO2e (84 percent lower than 1990 levels). A transition from natural gas to RE is anticipated to achieve a 39 percent RE share in the power generation mix by 2030 and 53 percent by 2050, compared to 23 percent in 2020 (figure 11). In terms of installed capacity, this shift would require installing 0.09 gigawatts (GW) of wind and 1 GW of solar capacity by 2030, and a cumulative total of 1 GW of wind and 7.3 GW of solar by 2060. Hydropower capacity is expected to increase slightly to 1.5 GW by 2060, up from 1.4 GW in 2020. Besides installing RE, the APS requires the adoption and implementation of policies to support energy efficiency improvements across all end-use sectors. These include energy efficiency standards for buildings and industry, biofuel mandates, emission performance standards, and a shift to electricity for heating and transport. Under the APS, total final energy consumption in 2050 would be about 35 percent lower than under the REF scenario. The APS also requires the installation of pumped and battery storage to integrate variable RE, and the reduction of fugitive emissions from the natural gas network (box 3).

Figure 11: Electricity sector indicators for the three energy-system scenarios



Source: World Bank staff calculations, based on CompactPRIMES modeling

Notes: In panel a, Power-to-X and other refers to zero-carbon fuels (e.g., hydrogen, renewable methane) generated from electricity. In panel b, gas refers to total gas generation, including natural gas and other low-carbon alternatives (by 2060, fossil natural gas is fully replaced by synthetic methane and hydrogen under the NZS); other includes biomass without carbon capture and storage.

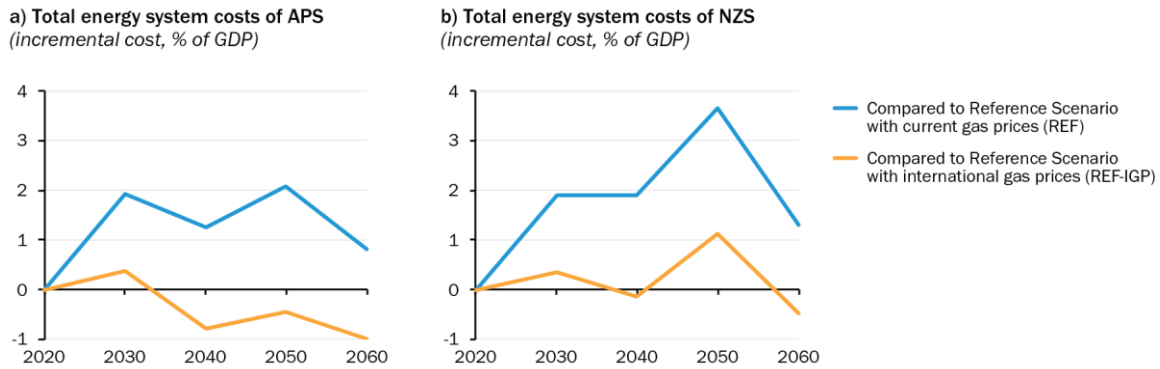
3.1.3. Full decarbonization by 2060 requires further accelerating emissions reductions compared to the Announced Policy Scenario, especially after 2030

The NZS requires a further doubling of GHG emissions mitigation rate, implying a much more rapid and profound transformation of the energy sector compared to the current policy and investment landscape. Until 2030, the development of key energy and power sector indicators is similar under the APS and NZS, as illustrated in figure 10. But the two scenarios diverge substantially after 2030,

modeling a 53 and 87 percent reduction in emissions between 2030 and 2050, respectively. By 2060, the NZS anticipates a 97 percent decline, almost double those projected under the APS. This much steeper emission reduction is achieved by deploying new technologies to replace most gas in power generation and switch the natural gas grid to low-carbon energy carriers.

The incremental total energy system costs of the NZS depend on the baseline and essentially disappear when compared to a scenario in which Armenia pays the energy security premium of diversified gas supply. Figure 12 shows the differences in total energy system costs of the APS and NZS compared to the REF and REF-IGP scenarios, as percentage of GDP. The modeling suggests that the net costs are modest when compared to the REF scenario, in which domestic gas supply arrangements are maintained and prices remain below international benchmarks (peaking at 2.1 and 3.7 percent of GDP in 2050 for the APS and NZS, respectively). The net costs turn negative in some years when compared to the REF-IGP in which gas supply sources are diversified and prices align with international benchmarks, which is equally energy-secure as the NZS. This suggests that the energy security premium of a diversified gas supply would cost Armenia, on a net basis, even more than replacing all imported fossil fuels with domestic

Figure 12: Total costs of decarbonizing the energy system under the APS and NZS, compared to different baselines



Source: World Bank staff calculations, based on CompactPRIMES modeling

The least-cost pathway to achieving net zero by 2060 implies a near-complete shift from natural gas and petroleum to electricity and electricity-derived fuels in the buildings, transport, and industry sectors, leading to surging electricity demand. In 2020, the share of electricity in the final energy demand accounts for 20 percent; this would rise to 78 percent in 2060, with zero-carbon energy carriers (such as biogas, synthetic methane, green hydrogen, and biofuels) contributing another 20 percent. Generating zero-carbon energy carriers, which require electricity for power-to-X applications—where X refers to hydrogen, clean methane, and other low-carbon energy carriers—is anticipated to consume about 9 percent of total net electricity generation. By 2060, this would necessitate an increase in electricity generation to 42 terawatt hours (TWh), nearly tripling the amount in the REF scenario and almost six times the 2020 NZS figure. In the residential sector, for example, electricity is anticipated to constitute the predominant portion of final energy demand under the NZS, reaching 83 percent by 2060. This shift is attributed to the widespread adoption of heat pumps for heating and cooling, electric cooking appliances, and water heaters. Conversely, gas consumption, including for heating, cooling, and cooking, is expected to fall sharply to 5 percent by 2060, in stark contrast to nearly 72 percent under the REF scenario. The gas used would be a blend that includes clean gas, biogas, and hydrogen, reducing the share of fossil natural gas to a negligible 1 percent of total gas consumption by 2055. The NZS also indicates a modest (11 percent) reduction in the use of biomass and solid fuels compared to the REF scenario for 2060, accounting for 9 percent of final energy demand.

The power sector would have to lead decarbonization, reaching near-zero emissions by 2045 through a shift from natural gas generation to new renewables complemented by hydropower and nuclear. Power sector emissions would have to decrease from almost 1.4 MtCO2e in 2020 to 0.1 MtCO2e by 2040 and to reach full economywide decarbonization by 2045. Key to this transition is accelerated RE deployment, particularly of solar power, the gross installed capacity of which is projected to increase over eightfold between 2030 and 2060. Under this scenario, variable solar PV and onshore wind generation would gradually replace natural gas consumption (acting as a fuel saver in the power grid) until it replaces nearly all gas generation, and start producing synthetic methane and hydrogen when production exceeds demand. In 2060, solar PV and onshore wind would represent 60 percent of total installed capacity (13.6 GW, compared to nearly 0 GW in 2020) and 54 percent of generation (42 TWh), with the remainder coming mostly from hydropower and nuclear.

Box 3: Eliminating fugitive emissions from the natural gas grid to enable the use of low-carbon gases under the NZS

About half of Armenia's methane emissions are from the energy sector in the form of fugitive emissions from the natural gas grid. Armenia's third biennial update report to the UNFCCC (submitted in 2021) indicates that methane emissions accounted for 30.6 percent of the country's total GHG emissions. These stem primarily from the energy sector, with approximately 52 percent due to fugitive emissions from the natural gas system. The GHG inventory reveals that the methane emissions were equivalent to 3.132 MtCO2e in 2017, including fugitive emissions from natural gas, enteric fermentation, waste disposal, and wastewater treatment (Republic of Armenia 2021). The IEA reports that, although monitoring and response mechanisms are in place, technical losses in the transmission and distribution systems account for 3.5 and 1.2 percent, respectively (IEA 2022). In 2022, the Public Services Regulatory Commission published Armenia's overall gas indicators, showing 2.76 percent transmission losses and 1.76 percent within the distribution system.

Since 2000, fugitive emissions have increased in line with natural gas consumption. The third biennial update report reflects that during 2000–17, fugitive emissions from natural gas transportation and distribution increased by around 47 percent, from 1.1 to 1.62 MtCO2e (Republic of Armenia 2021). Under the APS, fugitive emissions from gas transportation decline sharply due to the reduction of gas usage and cost-efficient measures driven by the carbon price. But there is still room for improvement, since much of the natural gas grid is old and inefficient, requiring investments and extensive rehabilitation works.

To achieve the net zero GHG emissions target, additional policy measures and investments are required to reduce fugitive emissions from the production and transportation of fossil fuels. Under the NZS, fugitive emissions would have to decrease from about 1.2 MtCO2e to near-zero in 2060, while under the REF scenario, they would need to fall by 11 percent. Notably, fugitive emissions, accounting for around 8 percent of total GHG emissions in the REF scenario by 2060, are expected to be eliminated by 2060 under the NZS. Achieving this target would require the full elimination of gas leakage by rehabilitating at least those parts of the gas distribution network that serve consumers who cannot shift to electricity—typically, larger industrial consumers and power generation. Without the measures to eliminate leakage, the use of low-carbon gases in the natural gas network would be unviable, severely constraining Armenia's technological options to decarbonize hard-to-abate sectors.

Battery storage solutions play a crucial role in enabling the growth of solar PV and wind on the path to net zero, complemented by grid reinforcement, regional integration, and a continued contribution of nuclear power. High levels of wind and solar penetration would have to be combined with a mix of fast-flexing technologies (such as batteries, reservoirs, and demand-side and fast-response gas combustion using synthetic methane) that ramp up and down in seconds to counterbalance short-term wind and solar fluctuations, and a share of dispatchable-base generation (such as combined-cycle gas turbines using synthetic methane and biomass) to counterbalance the seasonal, longer-term variability of wind and solar. Energy storage plays a major role in the NZS, with battery storage reaching a gross installed capacity of 5.5 GW by 2060, up from 3 GW in 2030. Achieving such a high level of RE

penetration would also require significant investments in strengthening the grid, with domestic grid reinforcements required to connect variable RE on the distribution and transmission levels and strengthen grid management and control to ensure a reliable power supply. Increased international interconnection capacity will enable the trade of renewable power in times of excess or shortage domestically, while the expected nuclear power plant replacement investments by the mid-2030s will provide a firm low-carbon power supply. In the medium term, gas-fired power also provides balancing and valuable flexibility to complement variable renewable generation.

Under the NZS, energy efficiency improvements complement the shift to electricity by substantially cutting final energy demand, compared to the REF scenario. In the building sector, the NZS forecasts that energy efficiency measures—such as improved thermal insulation standards of new buildings and extensive renovation of existing buildings—could cut final energy demand for heating and cooling by 53 percent by 2060. In the industrial sector, the energy intensity of production (measured in GW-hours per unit of output) declines across various sectors under the NZS through energy efficiency measures and electrification, with the chemical and building materials sectors experiencing the steepest declines, at 77 and 51 percent, respectively, between 2020 and 2060. Compared to the REF scenario, improvements in energy efficiency within building materials, iron and steel, and paper and pulp sectors were notably higher, often doubling or more.

In the transport sector, GHG emissions would be mainly reduced through a combination of reducing demand (*avoid* strategies), shifting to less carbon-intensive modes of transport (*shift* strategies), and adopting clean fuels and energy efficiency measures (*improve* strategies). Armenia's transport sector is expected to experience a significant increase in demand by 2060, with passenger transport activity, measured in passenger kilometers, growing by 92 percent and freight transport, measured in ton kilometers, by 173 percent (figure 13). Under the NZS, Armenia can meet these targets through fuel efficiency improvements and electrification, and by reducing final energy demand for transport services, by 33 and 47 percent for passenger and freight transport, respectively, compared to current levels. Specific energy consumption, measured in fuel energy consumption per vehicle kilometer, falls to about 29–75 percent lower for passenger and freight transport, respectively, under the NZS compared to 2020 across all transport segments, compared to just 22 and 17 percent lower under the REF scenario. A gradual rise in the share of public transport also contributes toward the sector's decarbonization under the NZS, aiming to achieve a 27 percent modal share for passengers by 2060 (up from 21 percent today). This will be driven by policies favoring public transportation through enhancements in service effectiveness and quality. In freight transportation, the proportions of road and rail transport are assumed to remain constant. By 2060, conventional fuels would be nearly phased out, with some residual use, mainly in aviation. The fuel mix would be dominated by electricity, clean fuels, hydrogen, and biofuels, while the aviation sector would incorporate synthetic kerosene and biokerosene blends. The NZS also assumes a 5 percent reduction in passenger transport demand to reflect the impact of 'avoid' strategies that reduce the demand for transport, such as integrating land use and transport planning, promoting mixed-use compact developments, transit-oriented developments, and enhanced digital accessibility for services.

The NZS envisions multiple policy actions to decarbonize the transport sector, covering motorization management and e-mobility transition, more competitive public transport services, and enhancement of logistics systems. These include the following.

- **Leveraging concession-based models for public transport provision to accelerate e-bus uptake:** The proportion of electric vehicles in the public transport fleet is expected to gradually increase to 50 percent by 2040. While the upfront cost of e-buses is significantly higher than their diesel counterparts, total lifetime ownership costs are often lower, given the savings in operational costs. Modern concession models with private operators can accelerate e-bus uptake by leveraging this

advantage under the right contract duration and remuneration conditions per unit of service. Other areas to explore for improving the financial viability of public e-mobility are unbundling of asset ownership (buses and charging infrastructure) and operations (service provision), and the eventual aggregation of e-bus procurement at national level to lower capital costs.

- **Introducing CO2 emission standards and more stringent local pollutant emission standards for both passenger and commercial vehicles**, including new and second-hand vehicle imports, supported by enhanced governance and strengthened enforcement of emissions testing:[29] To this end, Armenia can increase minimum local pollutant emissions standards for all vehicles to the European "Euro 6" standards,[30] aiming for the gradual phase-out of internal combustion engines in new vehicles. For second-hand imports, it can apply targets on average CO2 emissions per kilometer in a given year, complemented with a charges and credits scheme, or implement an upper energy use or CO2 emission thresholds per kilometer, differentiated by weight or footprint. This would require a simpler accounting and enforcement process than applying specific targets, as it avoids the need for regulated importers to develop their own accounting of averages and charge and/or credit scheme.

- **Introducing regulatory requirements for the early electrification of company fleets and other high-use vehicles, such as taxis, buses, shared vehicles, light-commercial vehicles:** High-use vehicles can be a key enabler of cost-effective electric vehicle deployment due to higher savings from energy and maintenance costs, which can offset higher upfront expenditures. This can stimulate early investment in vehicle charging infrastructure and increase the availability of affordable electric vehicles in the domestic second-hand market in the medium term. Specific CO2 regulatory requirements for vehicle fleets can be complemented with CO2-differentiated vehicle taxation for company fleets, or through corporate social responsibility reporting and/or GHG emissions mitigation obligations.

- **Reviewing short-term incentives to support the transition to electric vehicles, which may evolve from current VAT exemptions into CO2-differentiated tax schemes or feebates.**[31] As the number of electric vehicles increases in the medium term, tax incentives may need to evolve into self-funding schemes such as feebates, where more efficient vehicles receive rebates and less efficient vehicles are levied fees. Any feebate scheme would require periodical adjustments as efficiency improves to maintain the price signals and keep the program financially sustainable in time.

- **Supporting the deployment of publicly available charging infrastructure and introducing regulatory requirements for off-street-charging.** Public financial support would be necessary in the short-term but would decrease over time as the business case for private investment improves. Properly designed public competitive concession tenders for charging point provision to include multiple locations would allow cross-subsidization to limit the social inequalities of underserved rural or disadvantaged areas, while introducing regulatory requirements would ensure a minimum availability of charging points in public, new, or renovated private garages. Ensuring pre-cabling for all new constructions and major building renovations would secure the 'right to plug'.[32]

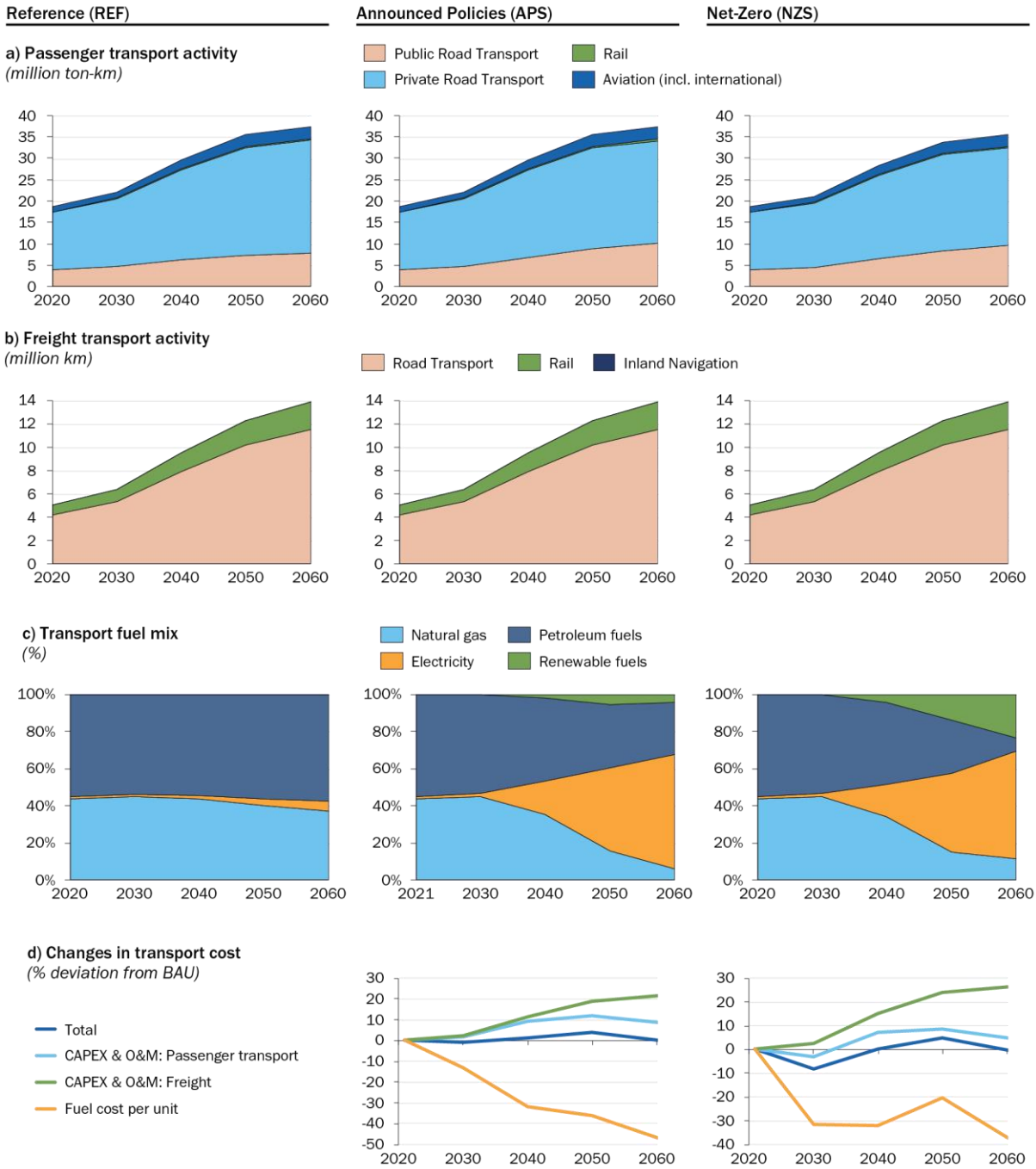
[29] UN Environment (2020) classifies Armenia's regulatory environment for second-hand vehicles as very weak.

[30] For an overview of Euro 6/VI vehicle emission standards, see ICCT (2016).

[31] The tax code already includes several tax incentives intended to promote the use of hybrid and electric vehicles. Other measures include exemption from local fees, including parking fees, for electric cars.

[32] The 'right to plug' refers to the right of any owner or tenant to install an EV charger for own use without unnecessary administrative burdens, provided they meet reasonable requirements, such as building safety standards, parking space availability, and no significant alterations to the building's appearance or esthetic (Rajon Bernard 2024).

Figure 13: Transport sector indicators across the three main scenarios (REF, APS, and NZS)



Source: World Bank staff calculations, based on CompactPRIMES modeling

The key energy system results under the NZS are robust to sensitivity analyses, but investment levels and electricity prices are impacted by assumptions about nuclear, solar land-use policies, and the reliance on synthetic low-carbon gases for hard-to-abate sectors. Three sensitivity scenarios were developed to assess the impact of key assumptions about power sector investments (box 2). The NNS, which assumes that Armenia will not replace the Metsamor nuclear plant, suggests that, in the context of a much larger power system in 2040 with substantially enhanced regional interconnections, it would be possible to replace nuclear power with commensurate increases in wind (increasing by 7 percent in 2060 compared to the NZS), solar (up 27 percent), and battery storage (up 38 percent), with incremental investment needs increasing by 0.33 percent of GDP by 2040, compared to the NZS. The

SLR scenario, in which land used for agriculture cannot be used for solar, suggests that there will be no land-use trade-offs between food production and energy when the country approaches net zero. The share of solar power in the country's total power generation declines from 48 percent under the NZS to 42 percent under the SLR in 2060. This leads to a 9 percent increase in average electricity prices compared to the NZS in 2060, with solar partially replaced by wind (which increases by 60percent in 2060) and hydropower demonstrating a slight (4 percent) increase in 2060, compared to NZS levels. Forcing the model to adopt a higher share of blended biomethane (from 19 to 30 percent) by 2060 to reduce the country's reliance on synthetically produced methane for the last mile of hard-to-abate sectors does not substantially change the cumulative investment by 2060 or total cost in 2060 (both are within 1 percent of the NZS results). This suggests that the overall conclusions are robust to the three sensitivity scenarios (NNS, SLR, and HBB).

3.1.4. Energy-security and other co-benefits of decarbonization

Under the NZS, Armenia would need to invest an additional $1.3 billion in the energy system over 2025–30, and $6 billion during 2025–60. Between 2021 and 2060, the necessary incremental investments compared to the REF scenario are: $0.2 billion in the transport sector, $3 billion in the power sector, $1.5 billion in the residential sector, and $1.3 billion in the industrial and commercial sectors.[33] This is equivalent to about 1.25 percent of the cumulative discounted GDP under the APS and 1.6 percent under the NZS. Mobilizing this investment would require an ambitious economywide policy agenda on top of announced policies (see chapter 4).

Energy sector decarbonization would allow Armenia to reduce domestic natural gas consumption and significantly decrease energy import dependency. Under the NZS, energy import dependency is projected to decline eightfold from around 74 percent of energy supply in 2020 to 9 percent by 2060, which would protect Armenia from supply disruptions that might occur from geopolitical conflicts or trade disputes. This shift is largely due to a significant decline in natural gas net imports—which are expected to fall from 24.9 to 0.026 TWh between 2020 and 2060—and a 70 percent reduction in oil net imports. The final energy consumption mix will be significantly transformed, with natural gas, which constituted 56 percent of the mix in 2020, projected to be phased out entirely by 2060.

The negative net cost of the NZS compared to the REF-IGP suggests that decarbonizing the energy system would strengthen energy security at a lower cost than diversifying gas imports. While gas has historically been imported at costs that are substantially below international gas price benchmarks, the modeling suggests that an increase in natural gas prices to meet international benchmarks would immediately make the low-carbon transition a no-regret decision. When considering the full economic costs of fossil fuels, therefore, decarbonization provides energy security at a relatively small or even negative cost and acts as an insurance against the uncertainty around future gas prices. This finding is robust even when only considering the period of deep decarbonization in 2035–60, suggesting that a delay in transitioning to diversified gas supply would not change the conclusions of the relative cost of the more gas-dependent and decarbonized pathways.

Armenia's industry could also take advantage of domestic clean energy development and become competitive in certain elements of global clean technology value chains. Armenia's domestic private sector is already taking advantage of opportunities in the clean energy sector, including solar module assembly and other smaller services and components along the solar PV project value chain. Provided that enabling conditions—such as access to finance and a clear regulatory framework—are in place, Armenia's entrepreneurs and businesses should be able to take advantage of the massive scale-up of clean energy and gain substantial market share in specific components, such as wind turbine towers

[33] All amounts are expressed in discounted terms (6% discount rate) and $2015. This excludes required investments in the strengthening of the power grid and EV-mobility charging infrastructure.

or solar PV mounting structures, or services. Certain gas worker skills could be transferable to other energy sectors, while thermal power plant operators and construction workers can apply their skills to power-to-X power plants and energy storage, as well as upgrade technologies for hydrogen, electric vehicles, and other innovative clean fuels.

There are also substantial synergies between building energy efficiency renovations and seismic resilience. Deep renovations carried out to improve thermal insulation can often be combined with structural strengthening measures to improve resilience against earthquakes. While the energy system model presented in this report does not cost such measures, experience from ongoing projects in public buildings and residential multiple-apartment buildings (MABs) financed by development partners, such as a Green Climate Fund-financed United Nations Development Programme[34] project with Armenian municipalities, suggests significant savings if both objectives are pursued jointly.

3.1.5. Managing the social and financial risks of the transition

Socially acceptable carbon pricing is one of the most important implementation challenges for achieving Armenia's climate ambitions. The (explicit) carbon price assumed in the modeling would have to reach $85, $106, and $210 per tonne of carbon dioxide (tCO2) by 2030, 2035, and 2060, respectively under the APS, and $97, $131, and $300, respectively, under the NZS. In parallel, under the APS, real average electricity tariffs (before carbon pricing) would increase from $79 per megawatt hour (MWh) in 2020 to $134 in 2030, declining gradually to $81 per MWh in 2060. Under the NZS, they would rise to $170 per MWh in 2030, falling back below current levels in real terms to $74 by 2060. Depending on how tariff increases are distributed across consumer groups, the impacts on households could be significant in the medium term. Because much of the increase is due to carbon taxation, the revenues of this can be (partially) recycled to protect consumers.

The government would need to carefully manage the clean energy transition to mitigate negative impacts on vulnerable consumers. This includes compensating for short-term price peaks through parallel social protection (SP) measures to avoid negative impacts on low-income households. Higher electricity and heating prices could severely impact households in Armenia, which already spend an average of 16 percent of their income on energy (20 percent for rural households), one of the highest in Europe and Central Asia, and much more than the affordability threshold of 5–10 percent. Survey data suggest that more than 40 percent of the population cannot afford to heat their homes properly and are therefore unable to reduce discretionary energy consumption. Implementing social security measures for lower-income and vulnerable consumers will help make the clean energy transition socially acceptable.

[34] https://www.undp.org/armenia/projects/de-risking-and-scaling-investment-energy-efficient-building-retrofits-undp-gcf-project.

Box 4: Phasing out traditional firewood use for heating in Armenia

As firewood-based heating and cooking contributes to forest degradation and indoor air pollution, disproportionately affecting women and children, shifting household heating to clean fuels is crucial. Although natural gas is the predominant source of heating in the country, nearly 23.8 percent of all households (51.5 percent of rural households) use firewood, while 11.3 percent of all households (25.8 percent of rural households) use wood for cooking (ARMSTAT 2023). High levels of fuelwood use in rural Armenia contribute to ongoing problems of forest degradation, while also increasing exposure to indoor air pollution, with women and children disproportionately affected when fuelwood is used for cooking. In this context, it is important to understand the drivers of fuelwood use to identify potential policy responses to limit its use and promote the shift to more sustainable sources as part of the energy transition in Armenia.

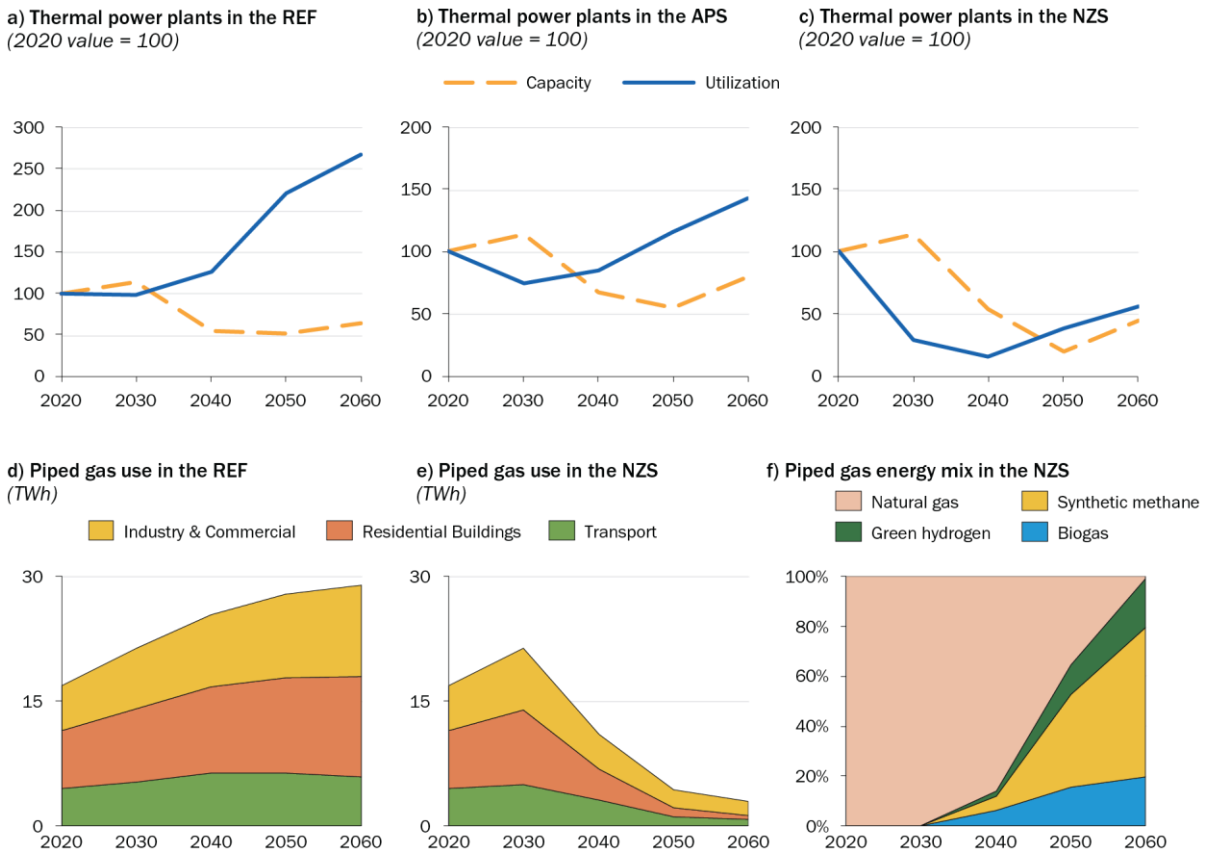
There is an intricate connection between income levels and fuelwood expenditure. Previous studies (such as World Bank 2020a) have shown that, on average, when gas prices increase, the Armenian population tends to use more fuelwood. But World Bank analysis of ARMSTAT household survey data for this CCDR indicates that use of fuelwood is as much (or more) a function of accessibility and preferences as affordability. Households source firewood in multiple ways, with and without cash expenditure, suggesting that only part of firewood consumption is influenced by the relative price of cleaner alternatives. Expenditure elasticity of annual wood expenditure across income deciles points to an equally complex relationship between income and fuelwood cash expenditure, with fuelwood use increasing when moving from lower- to middle-income deciles, before declining at the higher-income deciles. This pattern suggests that, while a systematically higher share of modern heating technologies is used by richer households, they also tend to have larger dwellings and may use more firewood, as the main or a complementary source of heating.

The transition to sustainable energy use in the residential sector will require substantial household investment. Overall, to transition to sustainable residential heating, the energy system model suggests that households will need to invest around $1.5 billion in discounted terms in energy efficiency and heating equipment during 2020–60 under the NZS. Annualized expenditure on residential energy equipment is expected to be between $200 to $300 per year per capita in undiscounted terms. This implies substantial pressure on household budgets, especially for low-income families, and risks increasing the use of fuelwood if no commensurate mitigation measures are taken to ensure the affordability of cleaner alternatives.

A mix of financial and nonfinancial policy interventions will be needed to encourage households to transition away from fuelwood. The government would need to compensate vulnerable households for welfare impacts from energy subsidy reforms and carbon pricing through parallel SP measures, as discussed in this section and section 4.4.2. But to ensure the energy transition does not increase fuelwood use, the recommended policy mix also includes behavioral policy interventions—including public information campaigns to raise awareness of the health and environmental impacts of using fuelwood—as well as subsidies to promote energy efficiency and fuel switching, and potentially, regulatory interventions. Public awareness campaigns and capacity building can educate households on the financial, environmental, and health benefits of sustainable heating solutions. Awareness campaigns on the health benefits of substituting fuelwood with other more sustainable heating solutions is crucial, especially in rural households. Energy efficiency grants, subsidized loans, rebates on old equipment, or other financial assistance to households can unlock investments in thermal building renovations and efficient clean heating system installations, such as heat pumps (standalone or coupled with solar rooftop systems) or solar water heaters. Such measures can substantially lower heating bills and make switching from firewood to electricity much more affordable. And once affordable alternatives are available, the government can use regulatory measures—such as phasing out inefficient heating systems in new buildings by banning appliances that are below a certain efficiency threshold or banning firewood use in certain districts—to trigger households' transition to sustainable heating solutions. Careful monitoring of forest areas, including through drones or geographic information systems, can help deter illegal deforestation.

Targeted measures to promote energy efficiency in buildings can play an important role in ensuring energy remains affordable, while also reducing GHG emissions. The building sector has substantial potential to make 40–60 percent energy savings across residential, public, and commercial sectors. Most of Armenia's buildings are residential, 52 percent of which are individual houses or single-family homes (SFHs), and 45 percent of which are MABs. Mostly built 30 to 60 years ago, the majority of MABs are overdue for reinforcement and renovation to extend their life. One recent study estimated that thermal modernization of MABs could save more than 1.25 TWh of final energy annually, preventing 0.25 MtCO2e per year (UNDP 2017). SFHs, though less well studied, represent an even more economically attractive opportunity for energy efficiency investment, especially in rural areas where building standards are often not enforced. Pilot programs are already underway to provide public grant financing to support energy efficiency investments in MABs and SFHs. Scaling these up and targeting them toward lower-income households, and creating a conducive legal and regulatory framework can help promote energy savings in new and renovated buildings.

Figure 14: Asset use in gas power generation and distribution, under three scenarios



Source: World Bank staff calculations, based on CompactPRIMES modeling

The risk of stranded assets in gas distribution and gas-fired power generation will need to be carefully monitored. Existing infrastructure will need to be transformed to accommodate the shift from natural gas to electricity as the dominant energy carrier. If Armenia is unable to develop zero-carbon gases that are cheap enough to be economically attractive for small consumers, the low-pressure parts of the gas distribution network, which have seen substantial investment, could become stranded assets. The gas grid is largely decarbonized under the NZS,[35] but still experiences a sharp decrease in total use by 2040, with consumption largely coming from larger, hard-to-electrify consumers (figure 14 d–f). This is

[35] The model does not consider the additional investment cost to accommodate these blends in the gas grid. Since hydrogen is the only gas in the blend with substantially different properties, and the share of green hydrogen is only 4% in 2060, this assumption is expected to have minor implications on the results.

due to a widespread shift to electricity for household heating, with electricity demand surging by 2040. This implies major losses of revenue for enterprises involved in the domestic natural gas market. Nascent technologies to produce zero-carbon gases also carry increased risks if these technologies do not achieve commercial scale and viability. There is also significant risk of stranded assets in thermal power generation, with the use of gas-fired generation assets declining by 71and 85 percent by 2030 and 2040, respectively under the NZS (figure 14 a–c). But the value of dispatchable gas-fired generation is likely to increase substantially in the market, so gas power plants may retain or even increase profitability, despite the lower use. Both these trends need to be carefully monitored.

3.2. Pathways for adaptation

Adaptation in Armenia will require a combination of infrastructure investments, CSA practices, and institutional reforms. This section explores the costs and benefits of multiple adaptation actions, reviews the country's progress in building the resilience of its public assets and services, and proposes additional policy and institutional reforms.

3.2.1. Investing in water conservation and efficiency, CSA practices, land restoration, and flood protection

Climate change will worsen existing trends in water scarcity, land degradation, and extreme events. As discussed in chapter 1, without action, climate change will exacerbate current trends, worsening water scarcity and land degradation, changing the seasonality of runoff, increasing unmet water demand for irrigation—particularly in Metsamor, Hrazdan, and Sevan Basins, where there is already tension over water resources—and leading to large decreases in crop and livestock yields. Natural hazards, such as floods and landslides, will also become more intense and compound with land degradation.

To reduce water scarcity and increase crop yields, the adaptation portfolios considered for this CCDR focus on improving water conservation and efficiency. Investments include: water storage; expanded irrigation in basins with large rainfed crop yield losses and no unmet water demand under future climate change scenarios; more efficient water conveyance systems; and more efficient on-farm irrigation technologies. Water storage is key for managing highly variable surface runoff, which is expected to increase in the spring and decrease in summer, and for ensuring sustainable water provision for irrigation. The CCDR considers nine adaptation portfolios with different levels of ambition for storing water, converting rainfed agriculture to irrigated agriculture, and upgrading efficiency for existing irrigation infrastructure. They include:

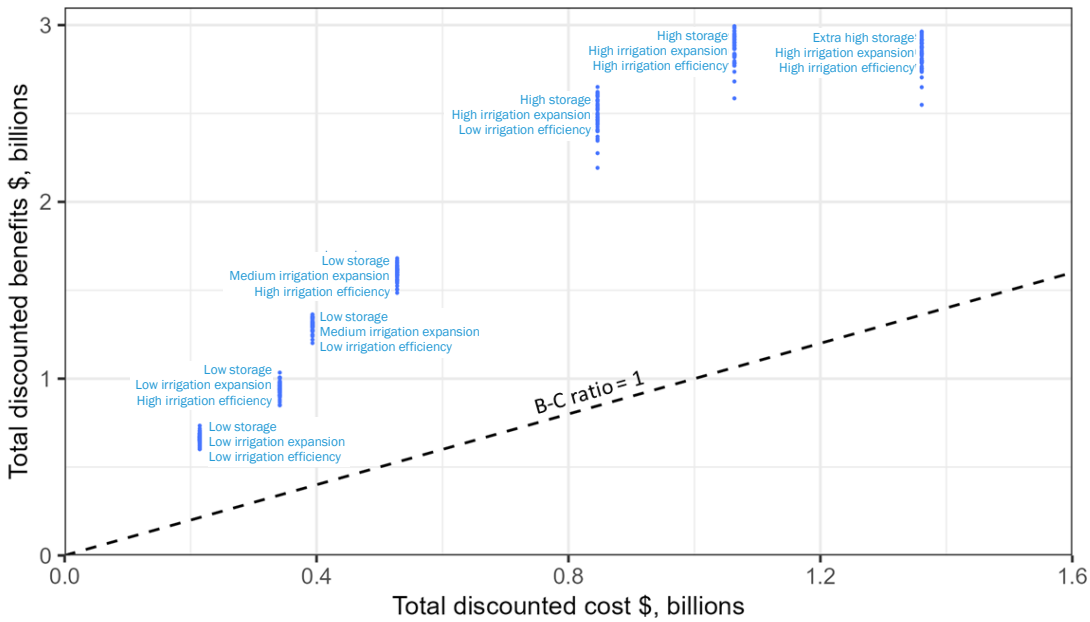
- The **ambitious adaptation portfolio**, with high storage, high irrigation expansion and high efficiency, which costs $2.3 billion (undiscounted) or $1 billion (discounted) and includes 15 new reservoirs for a total volume of 99 million cubic meters (an increase in total reservoir capacity of 7 percent compared to the current situation), investments to modernize and rehabilitate irrigation systems to increase irrigation efficiency from 40 to 70 percent in 2050 (nationally), and investments to increase irrigation for 75,914 hectares of agriculture land (a 66 percent increase compared to the baseline scenario)

- The **low ambition scenario**, which costs $440 million (undiscounted) or $210 million (discounted) and includes only four new reservoirs, increasing irrigation efficiency from 40 to 55 percent and irrigated land by 9 percent compared to the baseline scenario

- The **extra high storage scenario**, which costs $2.9 billion (undiscounted) or $1.4 billion (discounted) and includes 33 new reservoirs for a total volume of 575 million cubic meters (a 41 percent increase in storage capacity).

All portfolios have positive net present values (NPVs), but the ambitious adaptation scenario is superior in terms of both NPV and minimum regret. With the highest NPV—averaging $1.5–2 billion, depending on the climate change scenario—and the lowest regret (zero) across all climate change scenarios, the **ambitious adaptation scenario** is the preferred portfolio, whatever happens to future climate change. Adding more storage significantly increases the cost but brings limited additional benefits (figure 15). But if the budget is not available to implement a **high storage scenario**, the second-best portfolio is one with high improvements in irrigation efficiency and medium expansion of irrigated land. Indeed, increasing the efficiency of irrigation is much more cost-effective than storage: the cost of reducing water losses is $0.75 per cubic meter, while building new reservoirs costs at least four times as much ($3 per cubic meter).

Figure 15: Costs and benefits of adaptation portfolios in Armenia across 55 climate change scenarios



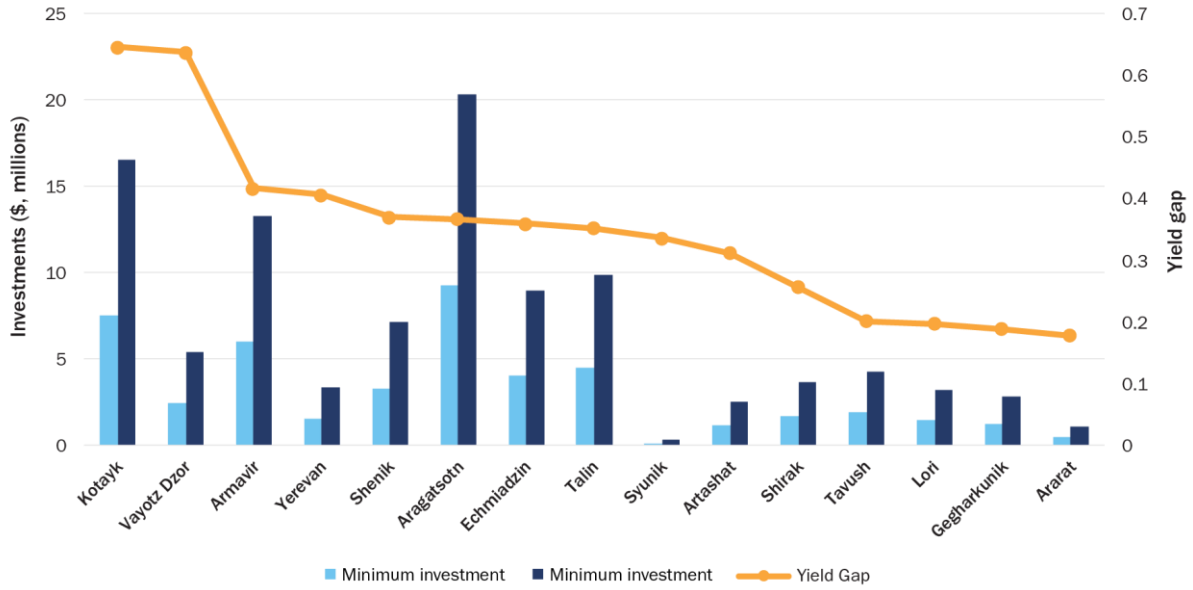
Source: IEc (2024).
Note: Numbers are discounted with a 6% discount rate.

Improvements in water efficiency could close yield gaps and reduce energy consumption. Using remote sensing to identify yield gaps due to irrigation inefficiency for the main crops in each of the water user association (WUA) in Armenia found that the largest yield gaps are for winter grains in Kotayk, hay in Vayotz Dzor, and hay in Armavir, at 65, 64 and 42 percent, respectively (figure 16). The lowest was for hay in Ararat, at 18 percent. Switching to modern on-farm irrigation technologies in the three WUAs with the highest gaps would cost $16–35 million, depending on the technologies used. Replacing irrigation systems with modern microirrigation systems in all WUAs would cost $47–103 million, increase yields by 36 percent, on average, for the main irrigated crops, and significantly reduce energy costs for water users through a combination of more energy-efficient pumping stations and a reduced need for pumping.

While the need for water storage is clear, a new masterplan would help refine the location, size, and timing of priority new reservoirs. The Armenian water authorities have not undertaken a masterplan since the dissolution of the Soviet Union, and the location and size of proposed new reservoirs dates back to that era. A detailed analysis of the economic performance of the 15 proposed reservoirs included in our adaptation portfolios, concluded that only three would have a high performance according to seven performance indicators; two would have low performance; and the other 10, a moderate performance (Sinha et al. 2023). In the short term, the government could prioritize the three

high-performance reservoirs and invest in a new water storage masterplan that considers both current conditions and possible future changes in water demand due to climate change.

Figure 16: Yield gap per WUA and investment needs in modern irrigation systems



Source: World Bank staff calculations, based on analysis by Karimi et al 2023.

As well as improving water conservation and efficiency, adopting CSA practices can help Armenia reduce agriculture yield losses. The country's variety of agroecological zones and diverse cropping patterns call for a region-specific approach to CSA promotion. For example, Gegharkunik and Shirak produce predominantly arable crops, such as grains, legumes, and potatoes. Agriculture in Ararat and Armavir is dominated by high-value crops, such as vegetables and melons, and perennial crops, such as fruits, nuts, and grapes. Farmers can adopt the following technologies: for vegetables, greenhouses, polytunnels, drip irrigation, water-saving hydroponic systems, and hydroponic or aquaponic systems that use soluble fertilizer; for perennial crops, on-farm drip irrigation and hail nets; and for orchards, suitable variety selection, considering drought tolerance and market relevance. In this report, simulations include switching up to 50 percent of crops experiencing the most heat effects to heat-tolerant varieties by 2050. Depending on the climate change scenario, these measures, combined with water conservation and efficiency portfolios, can halve or completely reverse crop yield losses. In the absence of adaptation, crop production shocks range from -6 to -15 percent for the wet/warm scenarios to -26 to -31 percent for the dry/hot scenarios by 2041–50. With adaptation investments, crop production shocks are reversed under wet/warm scenarios, reaching production gains of between +3 and +12 percent by 2041–50. While residual shocks remain under the dry/hot scenarios, production impacts are reduced to -10 to -16 percent—around half of the shocks projected without adaptation.

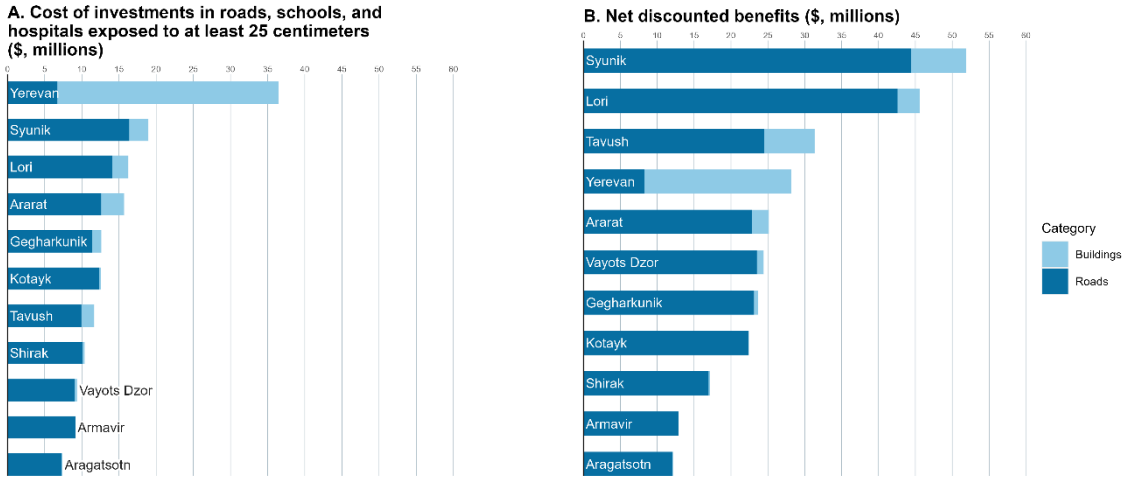
In combination with CSA, investing $40.76 million a year in land restoration can reduce climate impacts by increasing crop and livestock yields, erosion control, water regulation by reducing surface runoff, and slope stabilization. The restoration priority portfolio in adaptation hotspot areas was generated using the Resource Investment Optimization System (RIOS) model, which targets investments in soil and water conservation activities to achieve the greatest ecosystem service returns toward multiple objectives (Vogl et al. 2015).[36] In this study, the total area targeted for restoration activities was 150,000

[36] The RIOS approach was selected in this study because it provides an efficient way to optimize priority areas for landscape intervention without having to run multiple implementation scenarios through ecosystem service models to identify areas with the highest return on investment. Due to time and resource constraints, such a scenario-based approach was not feasible; instead, the study used the heuristic optimization model RIOS to identify the portfolio of priority areas, and then ran the resulting portfolio through ecosystem services models to estimate the improvements gained by implementation.

hectares, or around 20 percent of the area projected to be degraded by 2050. Because Armenia's wetland area is relatively small (540 hectares), all wetlands are targeted for protection and/or restoration in the portfolio selection. The allocation of the remaining area to interventions in forests, pasture, and croplands are proportional to the extent of degradation predicted in each of those biomes by 2050. This portfolio would entail investment across 5 percent of the country's total area.

The NPV of actions for restoring the recommended degraded land in Armenia during 2023–50 is $1.25 billion. If implemented properly, the proposed actions are expected to result in several benefit streams from the restored croplands, pastures, forests, shrublands, and wetlands. These include lower crop production costs, increased production of crops and livestock products, such as milk, meat, and wool, reduced infrastructure damage, enhanced supply of ecosystem services, and lower GHG emissions. The internal rate of return is 54 percent and the benefit-cost ratio (BCR) is nearly 4. The highest benefit in cropland restoration is attributed to increased crop production, lower cultivation costs, and the high rate of GHG emissions reduction. The far higher-than-average benefit of forest restoration results from higher rates of increased ecosystem services and GHG emissions reductions. Land restoration is still economically viable without considering GHG emissions reduction benefits, with a BCR of 1.44.

Figure 17: Costs and benefits of public flood management investments in buildings and roads, by marz



Source: World Bank staff calculations, using Fathom flood maps

Strengthening critical public buildings and roads can also help reduce flood risk in Armenia. Of the 562 schools and 114 hospitals that are exposed to flood risk, 60 schools and 13 hospitals are exposed to severe risk and would benefit from infrastructure strengthening. The total cost would amount to $41 million (figure 17), with BCRs of 2–4 in Lori, Tavush, Syunik, and Vayots Dzor.[37] About 40 critical emergency response facilities exposed to floods, earthquakes, and other major disasters could benefit from rehabilitation, strengthening, and/or reconstruction investments, with a total estimated cost of $45 million. For roads, priority investments to increase flood resilience are distributed across 13.6, 3.8, and 75.8 kilometers of primary, secondary, and tertiary roads, respectively, totaling $119 million. The BCRs are higher than 1 in all marzes, and can go up to 2.5 in Lori, Syunik, and Vayots Dzor.[38] A more ambitious scenario that targets all roads exposed to more than 10 centimeters of water would cover 125, 38, and 180 kilometers of primary, secondary, and tertiary roads, respectively, at a cost of $183 million.[39]

[37] These ratios only include avoided flood damages and do not consider other benefits, such as avoided learning loss in schools and avoided health services disruption in hospitals.

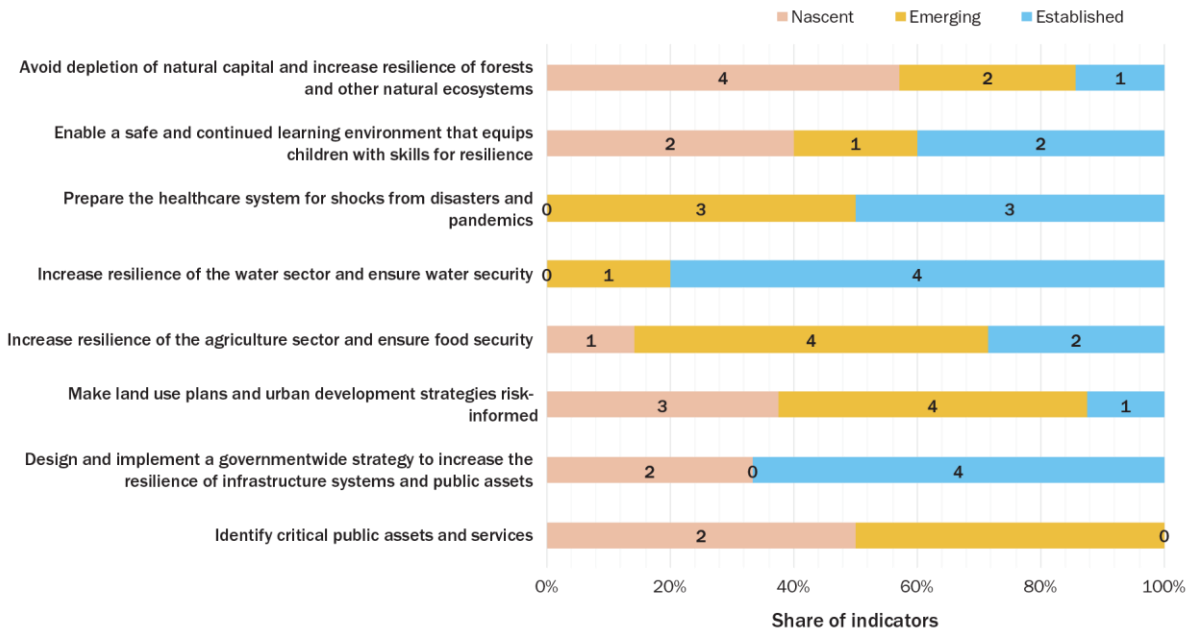
[38] These ratios only include avoided flood damages and do not consider other benefits, such as avoided traffic disruptions and associated economic losses.

[39] BCRs remain above 1, except in Armavir and Yerevan, where they are 0.9. But indirect benefits on traffic disruptions would make these investments profitable.

3.2.2. Policy and institutional reforms to promote adaptation

Armenia has taken many actions to increase the resilience of the water sector and ensure water security. An adaptation and resilience assessment conducted for this CCDR gives the country a high score for water resource management, with four out of five indicators set as 'established' (figure 18). For example, climate change vulnerability and adaptation considerations are integrated into the country's Water Code and existing and new water resource management strategies, plans, and legislation. Dedicated water resource management agencies are in place with functional coordination mechanisms, and a national water information system is used for decision making. In 2022, Parliament adopted amendments to the Water Code requiring that from January 1, 2024, all water users should install water flow meters with an online data transfer option, to allow the government to monitor water abstraction volumes.

Figure 18: Adaptation and resilience assessment indicators for Pillar 2: Adapting land use plans and protecting critical public assets and services



Source: Armenia Adaptation and Resilience Assessment, prepared for this report
Note: Number in each bar indicates the number of indicators per category.

But more policies and institutional reforms are still needed to strengthen water resource management and boost adaptation. To ensure sustainable of water resources management under uncertainty about future climate change impacts and transboundary water availability, priorities include:

- Allocating more resources to support the hydrological, agrometeorological, climate, and meteorological monitoring using geographic information systems
- Engaging stakeholders, including local communities, in water resource management decision-making, encouraging public participation and raising awareness about the importance of water conservation and sustainable use
- Making a strategic decision on the status of Lake Sevan (lake or reservoir) since it is increasingly being used to supply water for irrigation
- Continuing to make efforts to support transboundary cooperation with all neighboring countries and promote transboundary water management agreements, especially for shared rivers and basins, to address water resource challenges collaboratively
- Strengthening WUA institutional capacities and creating more favorable enabling environments to improve efficiency and implement environmental and rural development policies

- Implementing and enforcing regulations that limit the release of pollutants into water sources, including stringent controls on industrial discharges, agricultural runoff, and improper disposal of hazardous waste
- Developing and implementing an adequate tariff methodology for water supply systems and irrigation, reviewing and updating existing (outdated) irrigation norms, and reforming the ground and surface water abstraction fee system
- Undertaking a comprehensive re-evaluation of the volume of usable groundwater resources in the Ararat Artesian Basin, ensuring illegal water users (mainly for municipal and irrigation purposes) obtain water use permits, and revising water use permits based on the updated assessment of the volume of usable groundwater resources.

Despite the agriculture sector's high vulnerability to climate change, strategies for adaptation and food security are 'emerging'. Most agriculture support programs have only reached about 2,000 of Armenia's 300,000 farmers. The exception is a long-standing program that provides an interest subsidy on agriculture loans, which has 93,000 borrower beneficiaries. However, it has no specific agriculture development-related objectives and does not directly enhance farmers' knowledge or give them access to technologies that increase productivity and resilience. ND Gain's Food score reveals that Armenia has a high food insecurity risk.[40] The adaptation and resilience assessment scores Armenia as 'emerging' for most actions required to increase the resilience of the agriculture sector (figure 18). For example, its early warning system for the sector is only partially functioning for certain hazards, such as frost and risk of fire, with some hydromet information found on the Hydrometeorological and Monitoring Center's website, and a mobile application under development. An agricultural insurance system is in place, covering all marzes and insuring 13 crops against the risks of spring frosts, drought, hail, and fire. Scientific research on climate change adaptation and mitigation in agriculture is limited by the availability of human and institutional capacity, infrastructure, equipment, and financial resources.

Adjusting policies and agriculture support programs can ensure that all Armenia's farmers have the knowledge and access to CSA technologies they need. In its Agriculture Action Plan 2021–26, the government identified mitigation and adaptation measures related to CSA. Responding to climate threats will require promoting innovation in energy and water-saving technologies, waste management, circularity, and regenerative agriculture production, which requires a supportive environment for private sector investment. Training programs for farmers and subsidies or other incentives can encourage and promote the adoption of modern technologies, such as precision farming techniques, while region-specific information on current adoption levels will help with detailed CSA planning. Recording CSA activity among farmers in the 2024 agriculture census can help form a baseline for subsequent planning.

Climate action in agriculture requires an integrated approach that involves not only farmers, but also value chain actors, financial services providers, and nongovernmental agriculture service providers. This approach will provide an opportunity to implement comprehensive programs to improve resilience in Armenia's rural areas, especially among marginal and vulnerable groups. The adverse effects of climate change are exacerbated by socioeconomic and infrastructural deficits in rural areas, and efforts to increase resilience must consider the close interlinkages among stakeholders, including private sector actors that play a key role in value chain development. Beyond agriculture knowledge and technology, this involves an appropriate business-enabling environment that incentivizes climate action, innovation, agriculture credit, and insurance; crop marketing, food quality, and food safety

[40] The ND-Gain food score captures the vulnerability of a country's food system (production, demand, nutrition, population) to climate change. Indicators include projected change of cereal yields, projected population growth, food import dependency, rural population, agriculture capacity, and child malnutrition. https://gain-new.crc.nd.edu/ranking/vulnerability/food

certification mechanisms; and agriculture data and digitalization. Coordinating with the Water Committee on developing irrigated agriculture and the Ministry of Environment on landscape management planning and the implementing a green taxonomy to incentivize green investment in the agriculture sector will be key.

Armenia has made uneven progress in ensuring the resilience of health and education services. The adaptation and resilience assessment finds that Armenia has made progress on some indicators but is 'nascent' or lacks data in others (figure 18). While the country has developed and implemented plans to ensure a safe and continued learning environment, with guidelines and disaster risk reduction plans in all schools, the school buildings themselves are not built to standard and are vulnerable to earthquakes and climate hazards, putting hundreds of thousands of students at risk. On the health side, Armenia scores well for its emergency response plan, health risk communication, and surge demand capacity; but there are no data on hospital and health buildings' resilience to natural hazards, and it scores 'emerging' for quality of health care delivery.

While some measures are in place to manage critical public assets, Armenia could do more to increase their resilience. The country has an asset management system, construction standards for buildings, and an institutional structure for infrastructure resilience. But it has not established a systematic approach for identifying all its critical infrastructure and there is no comprehensive strategy—with sectoral resilience plans and actions—for their management. While Armenia has data on the vulnerabilities of its emergency response facilities and reservoirs, it has yet to comprehensively assess all its critical assets' vulnerability to climate and natural hazards. It has not allocated any budget for resilient infrastructure investments and there is insufficient funding for operating and maintaining existing public infrastructure, which increases its assets' vulnerability to hazards.

An overarching, comprehensive, and proactive strategy for identifying, managing, and protecting critical infrastructure risks is needed to provide the principles, policies, and priorities for safeguarding these systems. The strategy should be designed to enhance essential systems' ability to withstand, adapt to, and recover from a wide range of potential disruptions, and accompanying sectoral resilience plans could further define the necessary actions, finance, and funding initiatives to strengthen each sector's ability to withstand and recover from disruptions.

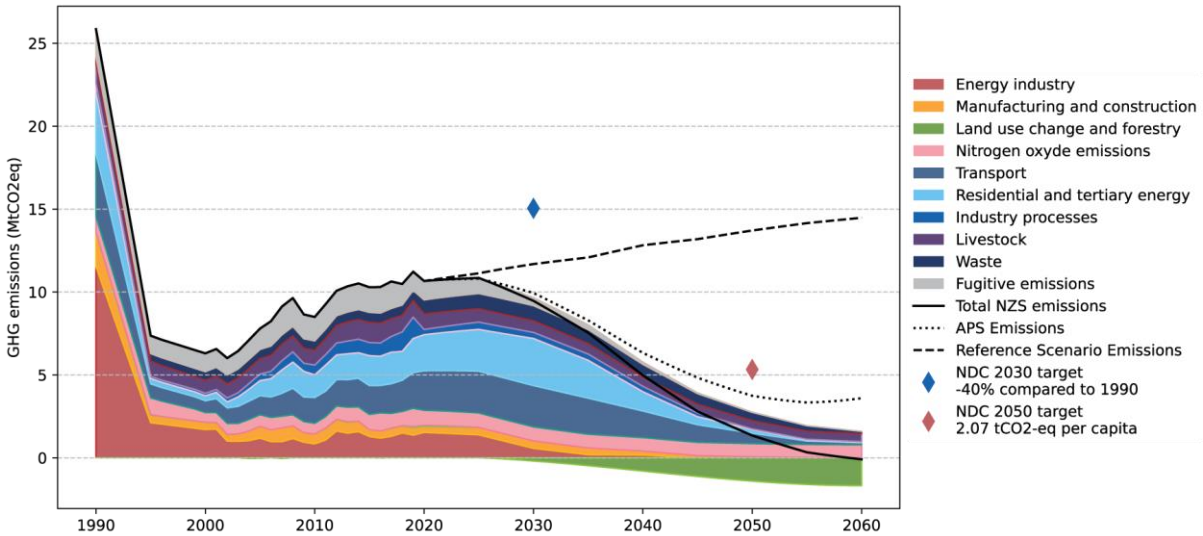
Armenia has put fewer efforts into managing its forests and degraded land areas. The adaptation and resilience assessment scores for indicators related to the depletion of natural capital and resilience of forests and other natural ecosystems are low—the country scores 'nascent' for four out of six indicators (figure 18). Armenia does not have a strategy for forest management or using nature-based solutions for adaptation and resilience. Although it is starting to put policies and measures in place to restore damaged or degraded natural areas, much more is needed. Priorities in this area include:

- Developing a landscape restoration approach as an element of a broader framework for the national adaptation plan so that initiatives are anchored to this broad goal
- Introducing rotational grazing or, if required, a grazing ban, when necessary, in the most degraded areas
- Strengthening economic incentives for CSA and forest landscape restoration investments by repurposing harmful agricultural subsidies into incentives for landscape restoration initiatives and introducing payments for ecosystem services
- Creating an enabling environment for innovations in climate adaptation through public-private partnerships (PPPs) in landscape restoration
- Piloting innovative landscape restoration models.

3.3. An integrated resilient low-carbon development pathway

This CCDR proposes a resilient net zero development pathway for Armenia with net zero emissions in 2060 and a more resilient economy. This will involve reducing energy-related emissions to 190,000 tCO2e, reducing agriculture emissions to 1.3 MtCO2e, and increasing carbon sinks to absorb 32.8 MtCO2e. To achieve this level of carbon sequestration, Armenia will need to make significant land use changes, reducing low-intensity grassland areas in favor of forests and increasing irrigated and rainfed intensive crop farming. These changes are also consistent with the investments identified to reduce land degradation and increase irrigated areas. Under this pathway, reducing the share of ruminants and monogastric animals in livestock farming would also reduce agriculture sector emissions from 1.8 MtCO2e in 2019 to 1.3 MtCO2e in 2060. Since ruminants are heavily impacted by climate change, this change also increases the sector's resilience to climate shocks. Emissions in the waste sector would fall to 13,000 tCO2e by 2060—a 95 percent reduction on 2019 levels—thanks to investments in solid waste management and the circular economy. As described in section 3.1, this CCDR also explores an alternative pathway that meets the government's target of 2.07 tCO2e per capita in 2050. In this alternative APS, energy emissions remain as high as 4.2 MtCO2e in 2060, and must be compensated by more stringent emissions reductions in agriculture and faster reforestation.

Figure 19: Total GHG emissions under the net zero pathway



Source: World Bank staff calculations based on the scenarios presented in chapter 3.

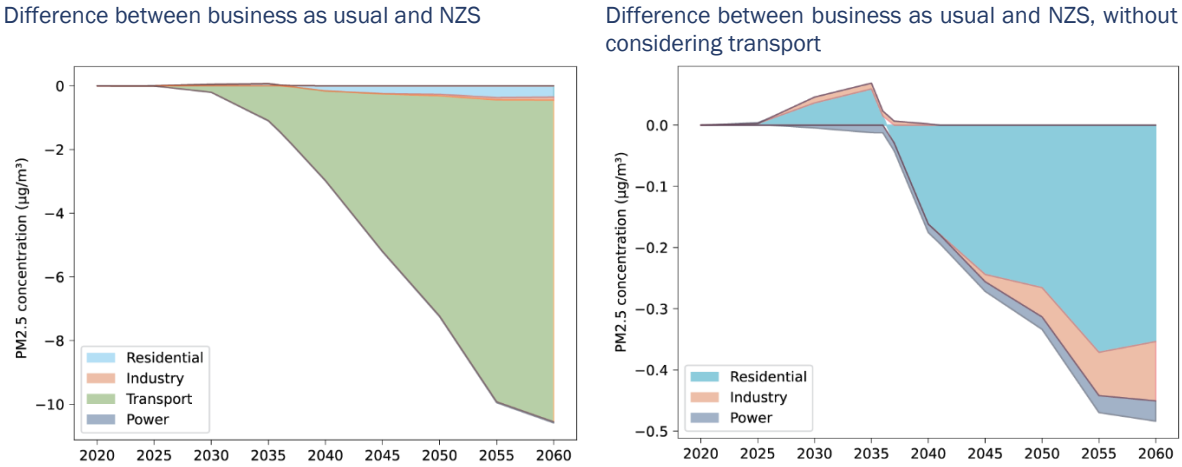
The resilient net zero development pathway would significantly reduce air pollution in Armenia, mostly thanks to transport decarbonization. As explained in chapter 1, air pollution is high in the country and a source of concern for Armenians. In the resilient net zero development pathway, emissions from transport, which are high contributor to air pollution, are almost completely eliminated, and residential air pollution from burning biomass is reduced by about 10 percent. Land restoration investments also reduce some of the pollution from dust, although most dust pollution is not due to anthropogenic activities. Altogether, these actions reduce PM2.5 concentration by almost 8 micrograms per cubic meter of air in 2060, or about 25 percent of 2020 concentrations.

The benefits of reducing air pollution in terms of reduced mortality amount to $650 million by 2060.[41] This corresponds to a 75 percent reduction in mortality from air pollution attributed to fossil fuels and a 2 percent reduction in mortality due to windblown dust. Additional benefits include lower morbidity and better mental health, cognitive ability, and productivity. And as reducing air pollution has a positive

[41] Using the value of statistical life and a 6% discount rate.

impact on labor productivity, it also affects growth, increasing GDP by 1–2 percent per year between 2040 and 2060 compared to a scenario that does not consider these benefits.

Figure 20: Reduction in PM2.5 concentrations in the resilient net zero development pathway, 2020–60



Source: World Bank staff calculations, using data from the Climate Policy Assessment Tool (CPAT)

The benefits of reducing air pollution in terms of reduced mortality amount to $650 million by 2060.[42] This corresponds to a 75 percent reduction in mortality from air pollution attributed to fossil fuels and a 2 percent reduction in mortality due to windblown dust. Additional benefits include lower morbidity and better mental health, cognitive ability, and productivity. And as reducing air pollution has a positive impact on labor productivity, it also affects growth, increasing GDP by 1–2 percent per year between 2040 and 2060 compared to a scenario that does not consider these benefits.

The combined impact of adaptation and mitigation policies on agriculture could boost productivity and exports from the agrifood sector. By improving water and fertilizer efficiency, reducing waste, and switching to CSA practices, farmers can save on inputs and increase revenues. Combining these measures with policies to continue expanding the capacity of the fast-growing domestic food processing industry, which is a significant contributor to job creation and (export) revenue, would further boost growth. Facilitating sustainable market linkages in the agrifood value chains through programs that support farmer integration and modernization, the widescale adoption of food quality and food safety standards, and value chain logistics—such as trade hubs and platforms for perishable products—will also help make the agrifood sector a key driver of green growth in Armenia.

Compared the REF scenario, a resilient low-carbon transition will require $2.5 billion in additional investments by 2035 and $5.5 billion between 2035 and 2060 (1.8 and 2.6 percent of GDP per year, respectively). Between 2035 and 2060, most of these investments will be to decarbonize the economy, particularly in the electricity sector, and most can be privately funded. Public investments will be required, however, in the transport and water sectors, and to some extent in the residential and agriculture sectors.

[42] Using the value of statistical life and a 6% discount rate.

Table 2: Investment needs of Armenia's resilient low-carbon pathway (NZS, ambitious adaptation portfolio), compared to REF scenario, until 2060

Sector	Net increase ($ billions, discounted) and average annual investments as share of GDP (%) between 2025-60	Estimated public/private split (%)*
Grand total	**8.0 (2.5%)**	**25/75**
Electricity	3.0 (0.9%)	7/93
Transport	0.2 (0.1%)	66/34**
Residential	1.5 (0.5%)	30/70
Industry and Other	1.3 (0.4%)	5/95
NZS total	**6.0 (1.9%)**	**16/84**
Water storage and irrigation efficiency	1.00 (0.32%)	80/20
Land restoration	0.61 (0.19%)	70/30
Resilient public infrastructure	0.18 (0.06%)	100/0
Agriculture	0.19 (0.06%)	10/90
Adaptation total	**2.0 (0.63%)**	**71/29**

Source: World Bank staff estimates, based on the modeling done for this report
Notes: Investments are discounted with a 6% discount rate. *Split is based on expert input, reflecting expectations for potential financial returns and Armenia's ability to mobilize private investment for these incremental investment categories, assuming that the policy recommendations of this CCDR are implemented. **Split refers to incremental investment in public and freight transport. The NZS foresees a net increase only in public and freight transport investment, and as the shift to public transport and 'avoid' strategies lead to lower overall demand, net private transport investment decreases. But in absolute terms, most of the transport investment is private.

4. Implications for poverty, inclusion, and the macroeconomic outlook

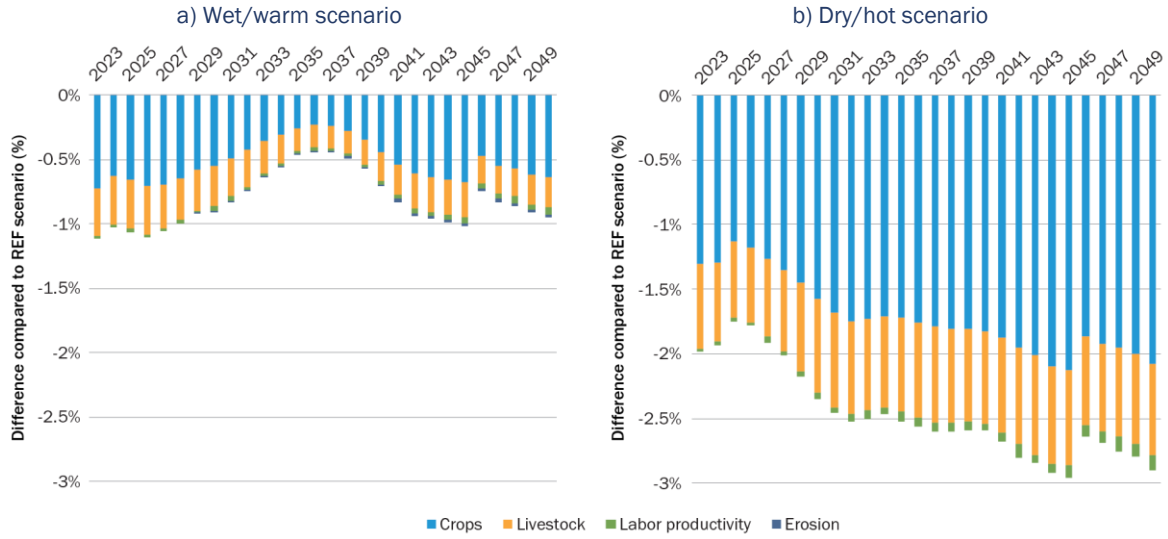
MAIN MESSAGES

- Climate change impacts impose a cumulative macroeconomic cost of 1–3 percent of GDP in 2060, depending on the severity of climate change. Adaptation increases GDP by 0.5–1 percent per year after 2030 compared to these scenarios, reducing the impact of severe climate change scenarios by 30 percent and completely reversing the impacts of more moderate climate scenarios.
- The transition to net zero imposes a macroeconomic cost of 1.5–3.3 percent of GDP in 2040 due to the considerable energy and transport investments required. But as capital stock improves and becomes energy-efficient, enterprises and households spend less on energy, dampening consumption, increasing savings, and accelerating growth by the 2050s. As a result, the net zero economy recovers to near or above baseline levels by 2060, depending on gas prices in the REF scenario.
- Fiscal risks mainly stem from climate-exposed government assets and contracts, necessitating a sector-specific understanding of climate risks to guide effective risk management. Climate adaptation and mitigation investments require fiscal space that could involve trade-offs.
- Carbon pricing is a keystone policy for triggering the green transition, but should be implemented as part of a policy mix.
- Climate change and higher food prices could increase poverty by 2.7 percentage points (pp) in 2030 compared to the REF scenario, while the net zero transition and higher energy prices could increase poverty by 0.5–3.2 pp, depending on energy prices.
- To protect vulnerable people, adaptation policies and investments can be targeted to the regions that are most affected by climate change and have higher poverty levels, to reduce regional inequalities. Carbon tax revenues can also be used to protect poor people against higher energy prices.
- With increasing demand for low-carbon goods and services, some sectors present opportunities for growth and job creation, including apparel and textiles, critical minerals, and environmental services, which can thrive on the backbone of a robust services sector driven by information and communications technology (ICT).
- Financing the transition will require massive investments, but Armenia's energy system is well-suited to attracting private sector capital to close the mitigation investment gap. Domestically, green financing is growing but underused, so developing a green taxonomy and sustainable financing framework will be crucial to catalyze private investments in the transition.

4.1. The macroeconomic impacts of adaptation

Without action on adaptation, the combined effects of climate change across key impact channels could reduce Armenia's GDP by as much as 3 percent by 2050. Impacts on crops, livestock, labor productivity, and erosion would reduce GDP by 2050 by 1 percent under a wet/warm climate scenario, and by 3 percent under a dry/hot scenario, compared to a scenario without climate change. Most of these impacts are due to crop or livestock yield losses, with impacts of heat on labor productivity having a small effect toward the end of the period; erosion impacts are negligeable (figure 21). These impacts only reflect average changes and not extreme events, and they do not capture all possible negative impacts on GDP, such as the impacts of floods on supply chains and exports through transport disruptions or the possible persistent negative impacts of consecutive droughts.

Figure 21: Climate change impacts on GDP under wet/warm and dry/hot scenarios without adaptation, compared to the REF scenario

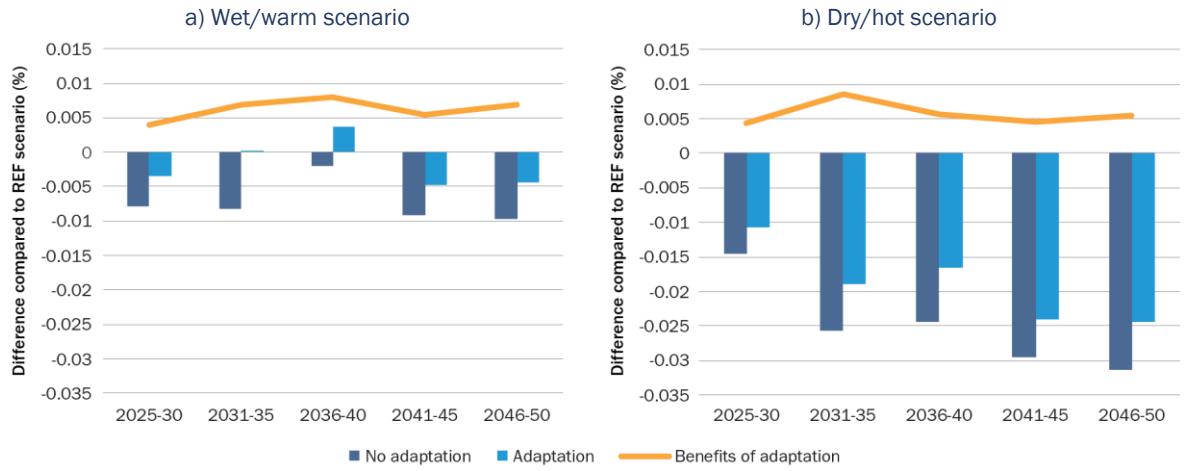


Source: World Bank staff calculations, using MANAGE-WB and IEc data

4.1.1. Macroeconomic benefits of adaptation investments

Adaptation investments reduce the impacts of climate damage and increase GDP by 0.5–0.7 percent per year, on average, compared to a scenario without adaptation. The adaptation investments in water and agriculture for the ambitious adaptation portfolio described in section 3.1 require additional spending of 0.33 and 0.28 percent of GDP per year by 2035 and 2060, respectively. These investments would increase annual GDP by 0.7 and 0.6 percent under hot/dry and wet/warm climate conditions, respectively, compared to scenarios without adaptation. Under warm-wet conditions, adaptation eliminates climate damages for most years between 2022 and 2060, and can even increase GDP compared to the REF scenario (figure 22). But under more severe (hot/dry) climate change, adaptation does not prevent all climate change impacts and GDP remains 1–2 percent lower than in the REF scenario. Adaptation spending supports household consumption, consistently reducing the impact of damages under both climate conditions. Net exports are also higher, and agricultural production has a higher share in value added.

Figure 22: GDP under different scenarios with and without adaptation, compared to the REF scenario (%)

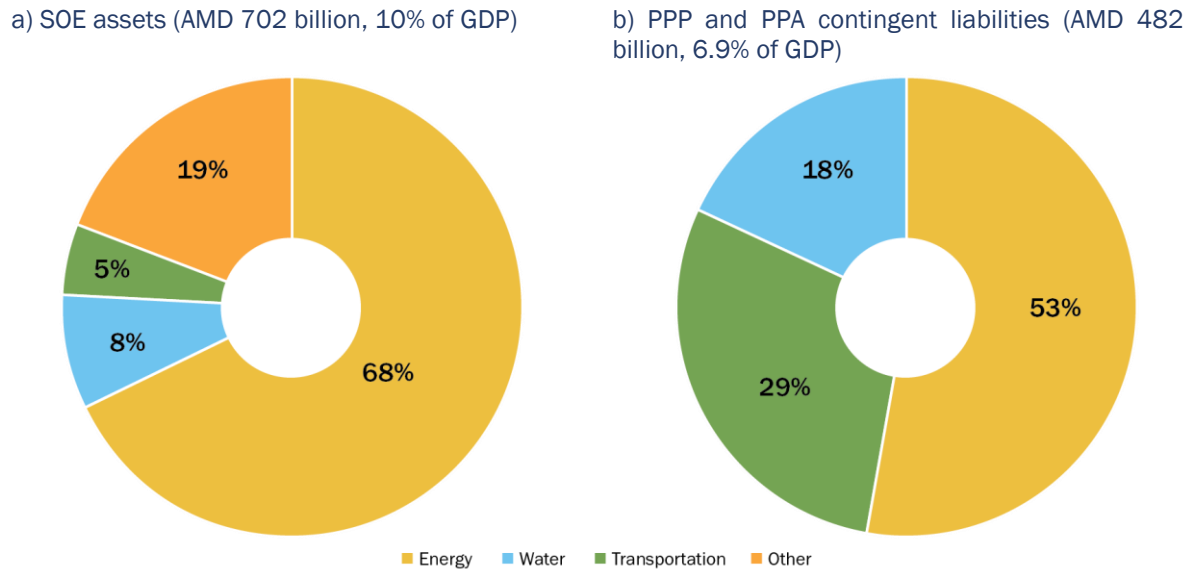


Source: World Bank staff calculations, using MANAGE-WB and modeling on adaptation

4.1.2. Managing fiscal and financial sector risks from climate change

Armenia needs to better quantify and manage current and potential contingent liabilities emerging from climate physical risks that have fiscal and financial implications. Government assets and contracts, including those in PPPs and state-owned enterprises (SOEs), are particularly susceptible to climate variability and natural disasters, with significant exposure in the energy, water, and transport sectors (figure 23). Fiscal and financial stability risks stem from power purchase agreements (PPAs) in the energy sector, other major long-term contracts, and contingent liabilities from a water sector PPP. Climate change poses risks to existing infrastructure and investment projects, necessitating quantification and understanding of their exposure. Armenia significantly lags peer group countries in developing a financial strategy to manage contingent liabilities and setting up systems for communicating and mitigating disaster and climate risk exposure in the private sector and pension systems. Project appraisals and selections should assess fiscal risks related to physical climate and the structural factors that underpin decarbonization or are related to a price or supply shock to natural gas. Armenia is vulnerable and must strengthen its countercyclical fiscal policy and build fiscal buffers, including through its stabilization fund.

Figure 23: Percentage of firms in high climate risk sectors, by sector



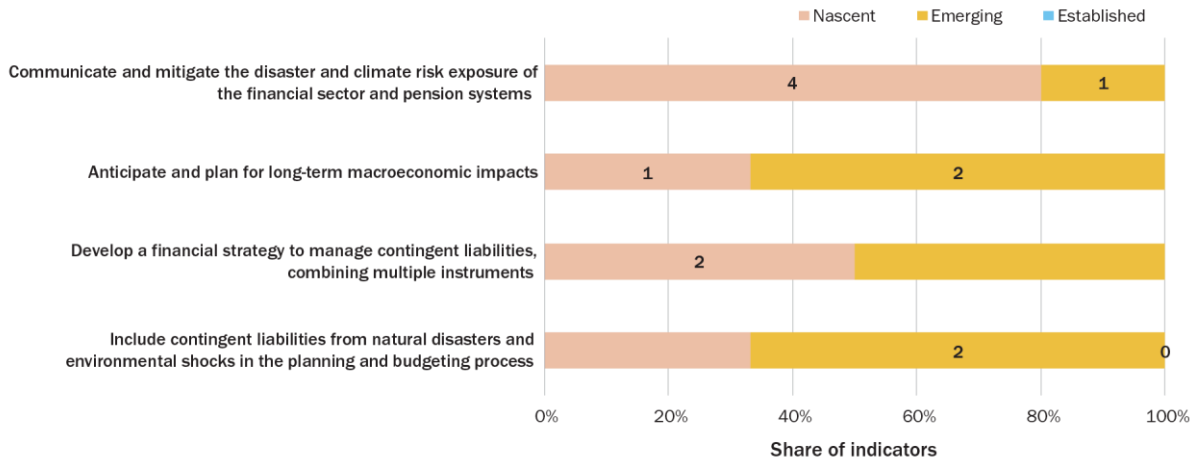
Source: Republic of Armenia 2022

Climate and disaster risks are not considered in business processes and portfolios, and quantified estimates of exposure to natural hazards by banks and large investors are not available (figure 24). About 29 percent of the Armenian banking system's loan portfolio comprises loans to climate-vulnerable sectors, and 19 percent are mortgage loans, with buildings or apartments as underlying assets, which may be subject to physical risks (Central Bank of Armenia 2023). Armenia does not have specific disaster and climate risk requirements in regulations for banks, insurers, and large investors, and there are no climate and disaster risk stress tests for banks or investors. All these gaps underline the urgency for Armenia to work on enhancing adaptation and resilience by improving financial and macro-fiscal management. This section summarizes some of these gaps, extracted from recent evaluations within the country.

Armenia needs to further integrate climate risk, adaptation plans, and investment needs in its public investment management (PIM) and budgeting. It should regularly evaluate climate change-related fiscal risks, including compensation schemes for landowners during droughts, financial sector risks,

and climate-related risk management in central banks.[43] Its PIM process already includes climate screening of projects, but setting sound overarching national adaptation and resilience strategies to assess individual projects against would ensure close tracking and delivery of projects deemed a priority for climate action and the analysis of climate change risks and projects' impact on meeting Armenia's mitigation targets. Developing a comprehensive risk management strategy that incorporates sector-specific climate risk analyses, adaptation plans, and investment needs, and is integrated with the budget process and medium-term expenditure framework would ensure Armenia's fiscal sustainability. This will require improving data collection and processing systems, expanding and upgrading hydrometeorological observation networks, and strengthening data collection.

Figure 24: Adaptation and resilience assessment: capacity to manage financial and macro-fiscal issues



Source: Armenia Adaptation and Resilience Assessment, prepared for this report
Note: The numbers in each bar indicate the number of indicators per category.

4.2. The macroeconomic implications of decarbonization

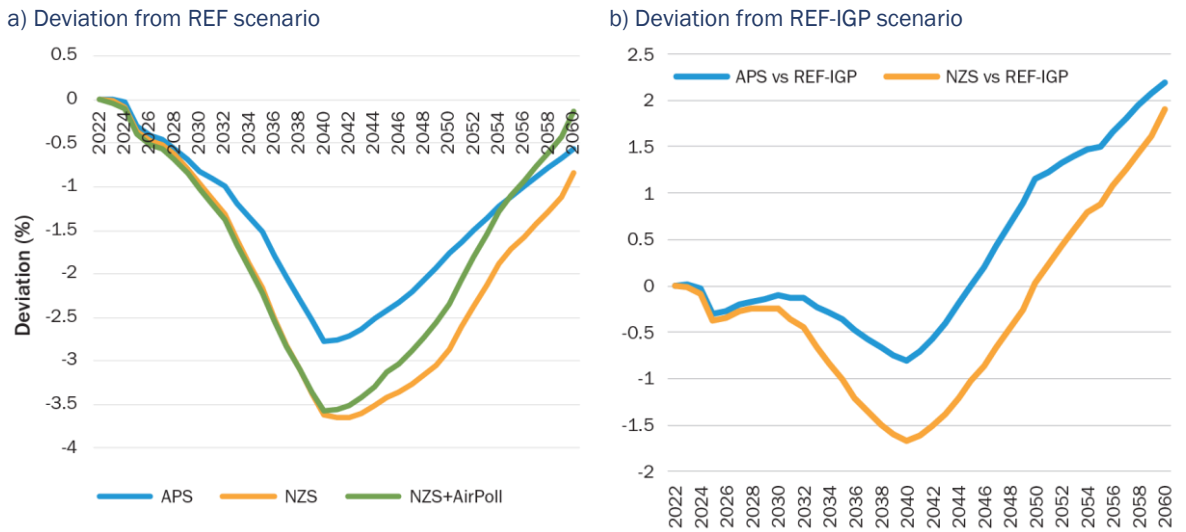
With ambitious climate action, Armenia can meet its climate targets without suffering significant loss in GDP growth. Analysis based on a CGE model for Armenia provides new estimates on the impacts of the climate transition on growth under a range of scenarios (box 5). Although the economy contracts in the short to medium term, peaking at -3 percent in the 2040s, the impact on economic growth is modest in the long term and reduces by less than 1 percent per year by 2060 compared to the baseline under both the APS and NZS. So, a more ambitious net zero policy approach (relative to APS) does not significantly compromise growth in the medium term and will lead to higher growth over the longer term (figure 2**Error! Reference source not found.**5a). And when considering co-benefits from emissions r eductions due to lower air pollution (under a scenario called NZS + Airpoll), which contribute to growth through higher labor productivity, there is no difference in GDP in 2060 between the NZS and the baseline scenario.

When compared to the REF-IGP scenario, decarbonization leads to positive impacts on GDP after 2050. Given the importance of fossil fuel prices for an energy-importing economy like Armenia—both for its macroeconomic impacts and the pace of a transition to net zero—an additional scenario was run in which Armenia does not decarbonize but diversifies its gas supply and starts paying international gas prices. This is a plausible scenario, given that the 2010 Russian gas tariff increase led to a nearly 40 percent increase in retail gas price for residential consumers and hit Armenia's economy hard, particularly impacting households that rely primarily on gas for heating and cooking (Ersado 2012). Importing gas

[43] For sample central bank activities, see https://www.ecb.europa.eu/ecb/climate/html/index.en.html and https://www.bankofengland.co.uk/climate-change.

sold at international prices would increase household and enterprise energy costs, increase price inflation, negatively affect the balance of payments and currency stability, and increase current account deficits. Price volatility due to regional and geopolitical tensions, supply disruptions, and the pace of global transition also compound the impacts of economic instability. Under the REF-IGP scenario, the share of gas falls faster and the price of renewables increases faster than under the REF scenario. Less gas also means more electricity and refined petroleum goods in the energy mix. Compared to this scenario, the impact of decarbonization on GDP is more moderate in the short term but positive from 2040 under the APS and from 2050 under the NZS (figure 25b), showing that in the long run, it is preferable for Armenia to decarbonize the economy than risk having to pay higher gas prices.

Figure 25: Real GDP under APS and NZS, 2022–60



Source: World Bank staff calculations, using MANAGE-WB
Notes: Real GDP is calculated at market prices.

Mitigation and adaptation investments reinforce each other and would improve overall productivity, leading to stronger and more resilient growth as early as 2030. Integrating climate mitigation and adaptation would reduce the short-term costs of mitigation, since adaptation increases GDP by 0.5 percent per year on average as soon as 2030. The two sets of actions combined can promote technological advances, achieve multiple objectives simultaneously, and reduce costs—for example, in the agriculture and infrastructure sectors. Adaptation can reduce risks from physical damages, safeguard economic assets, and diminish disaster recovery costs, which in turn stimulates investment. Such investments and innovations in green technologies, CSA, and resilient infrastructure can also spur green growth, opening up new markets and consequent job opportunities, while ambitious climate action can help the economy gain a competitive advantage in emerging green product markets.

Investment policies and introducing a carbon price can help shift the economy to a net zero path. Ambitious climate action can increase the domestic cost of production with impacts on prices and consumption. But, depending on assumptions on the recycling of carbon tax revenues, policies can be designed to safeguard growth, support government spending, improve incentives for workers, and protect low-income households. Under the NZS, the carbon tax rate would rapidly increase, leading to tax revenues that are 6.7 percent higher than REF levels in 2030. Overall tax revenues increase despite a reduction in labor taxes. As the economy decarbonizes, these tax revenues gradually decline.

Investment costs initially weigh on growth but lead to improved capital stock, energy efficiency, and savings. As discussed in chapter 3, achieving net zero will require considerable investments, particularly in transforming transport and energy systems, enhancing energy efficiency, decarbonizing industrial processes, and developing clean energy storage. Under the NZS, government capital

expenditure is 17 percent higher in the mid-2030s than under the REF scenario, before falling to more than 7.4 percent above the REF level by 2060. Given the scale of the investment needs, there is crowding out, although firms partially finance investments, reducing this effect. Lower energy costs from more efficient energy also leads to enterprise savings, which contribute to capital accumulation and further investment. Household consumption follows similar patterns. Energy savings associated with the transition reduce consumption and increase capital accumulation, offsetting investment needs in the 2030s and 2040s.

Box 5: Macroeconomic modeling and scenarios: impact on economic growth, financial stability, and debt sustainability

The World Bank's Mitigation, Adaptation and New Technologies Applied General Equilibrium model (MANAGE-WB) is a single-country recursive dynamic CGE model designed to support World Bank teams and clients in macroeconomic analysis in a wide range of topics. It includes a detailed energy specification that allows for capital/labor/energy substitution in production, intra-fuel energy substitution across all demand agents, and a multi-output, multi-input production structure.

The application of MANAGE-WB for Armenia uses core data based on the 2017 Social Accounting Matrix from the Global Trade Analysis Project (GTAP) database, updated with macro and labor data for 2022, along with projections for population trends, economic growth, the mining industry, power generation, and energy consumption through to 2060 provided by sector-specific teams. This chapter outlines findings based on various scenarios that incorporate the effects of climate change, adaptation strategies, and mitigation efforts. It also discusses methods for comparing these scenarios to assess the impact of different policies.

The analysis of the economic implications of policy action to support a green transition is based on two scenarios, APS and NZS, and a baseline—the REF scenario—which assumes that Armenia continues to implement its current economic reform program but does not take strong measures to decarbonize. Under REF scenario assumptions, the returns to ongoing reform programs intended to make domestic markets more competitive, open access to external markets, and develop education, finance, and labor markets are expected to yield rapid GDP growth and rising productivity.

Scenarios and key assumptions

The APS involves the implementation of a carbon tax, environmental laws, regulations, standards, mandates, and energy-efficiency investments, alongside a comprehensive shift toward electrifying the economy. These measures are designed to achieve APS targets by 2030 and lower per capita emissions to 2.07 tCO2e by 2050. The NZS envisions the adoption of even more rigorous policies and efficiency enhancements, which will allow Amenia to reach net zero emissions by 2060.

Under both scenarios, the revenue from the carbon tax is redistributed as follows:

- 40 percent to reduce labor taxes
- 30 percent to increase public investment
- 30 percent to support low-income households (bottom 40 percent) to soften the impact of the transitions.

Both scenarios place a cap on the debt-to-GDP ratio of 50 percent, in line with Armenia's fiscal rules framework.

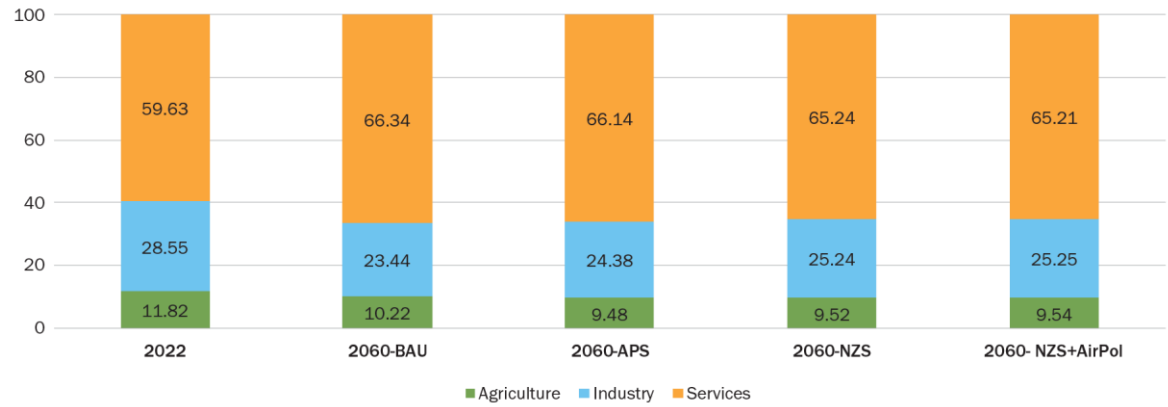
A third scenario, NZS+Airpoll, includes co-benefits from reduced air pollution estimated by the Climate Policy Assessment Tool (CPAT)[a] in the NZS.

The modeling assumes that climate change affects the economy through five channels: heat stress, soil erosion, livestock, crop yields, and hydropower generation. These shocks affect labor productivity, land productivity, livestock activities, crops activities, and hydropower production in the MANAGE-WB model. This chapter presents the results from two representative climate scenarios: wet/warm and dry/hot.

a) The CPAT was developed to help countries provide a rapid evaluation of the potential impacts of climate policy reforms. As a global tool covering more than 200 countries, it can be used as a one-stop-shop to provide a quick diagnostic of the potential benefits of a carbon pricing reform across key dimensions. It allows for the rapid quantification of impacts of climate mitigation policies, including on energy demand, prices, emissions, government revenues, welfare, GDP, household and industry incidence, local air pollution and health, and many other metrics.

In the context of continued structural transformation of Armenia's economy, the transition accelerates the shift out of agriculture and increases the share of manufacturing while boosting exports in the short term. The transition takes place in the context of a significant structural transformation of the Armenian economy, with continuing shifts from agriculture and manufacturing toward services under the REF scenario (figure 26). While the manufacturing share of the economy declines over time under the REF scenario, it continues to expand in real terms, and by 2060, is at least four times larger than in 2022. Under both the APS and NZS, there is an increase in the share of industry in total value added while the share of agriculture decreases. Services are mostly unaffected. The manufacturing share of value added is 5 and 9 percent higher in the 2040s under the APS and NZS, respectively, relative to the REF scenario. Both imports and exports expand at similar levels to production. Net exports in real terms are consistently between -4 and -5 percent of GDP. Under the NZS, net exports deviate by -20 percent from the baseline in the 2030s before recovering to +3.7 percent by 2060.

Figure 26: Sectoral share of value-added, 2022 and 2060



Source: World Bank staff calculations, using the MANAGE-WB model

Debt levels are capped around 50 percent of GDP in all scenarios, in line with Armenia's current fiscal framework. Total government expenditures and revenues are estimated to remain stable at 24–25 percent of GDP under the REF scenario, with a slight decline from the 2040s. Under the NZS, revenues and expenditures are initially higher compared to the REF scenario, due to supporting low-income households and increasing investment with the proceeds of the carbon tax, but expenditure sharply falls from the late 2040s and revenue is 2.5 percent lower than the REF scenario by 2060. This is because tax revenues from the carbon tax are only temporary and diminish as the economy moves toward net zero after 2050. However, new bases of taxation could address this shortfall. Interest payments on debt increase to 5 percent relative to REF levels by 2060.

4.3. Financing the transition

Delivering a resilient net zero development pathway in Armenia will require additional investments of $8 billion between 2025 and 2060 (2.5 percent of GDP per year). A policy package combining planning, fiscal policy, sectoral reforms, and institutional reforms can incentivize the transition and mobilize the funds required for these investments, and ensure that vulnerable populations do not suffer from the transition.

4.3.1. Fiscal policies with a focus on carbon pricing

Armenia has a low total carbon price (TCP) by international standards, driven by low energy taxes. By capturing both direct and indirect forms of carbon pricing—such as a carbon tax or an emissions trading system, and fuel excise taxes or fossil fuel subsidies—Armenia's TCP provides an overall price signal for

carbon emissions. The estimated 2022 TCP[44] for the whole economy is around $12/tCO2. This is low compared to European countries, which usually have a TCP above $150, and lower than select peers such as Georgia and Serbia, with TCPs around $21 and $44/tCO2, respectively (World Bank forthcoming, a).[45] Armenia's TCP is solely related to energy taxes; there are no explicit carbon prices, VAT deviations,[46] or fossil fuel subsidies, as it has already made significant progress in eliminating and phasing out subsidies to the energy sector, and tariffs are set at cost recovery levels.[47] Its positive TCP in 2022 is largely driven by taxes on kerosene, gasoline, and diesel, with natural gas taxed at a lower rate (but no longer subsidized) and coal having a TCP of almost zero.

Carbon pricing can be implemented alongside other pricing instruments and environmental taxes. Introducing an explicit carbon price through an upstream carbon tax or scaling up existing fossil fuel excises would be an effective means to spur the private investments needed to reach net zero emissions. A carbon tax can play a pivotal role in supporting the achievement of climate commitments by incentivizing private investment and generating revenues for public investment and to compensate vulnerable households. Upstream carbon taxes can enable the taxation of the whole economy, including the informal sector, at low administrative cost, with few evasion opportunities due to physical infrastructure and emissions traces, reducing compliance costs and corruption opportunities. This assumes that the optimal design is politically feasible and administratively implementable. Price impacts on the poorest, including from energy and transport price increases, can be offset with carbon tax revenue.

Complementary policy instruments may also include the creation of markets, support for technology diffusion and feebates. Carbon taxes have been effective at making some high-carbon activities unprofitable, but evaluations and evidence suggest they are less suitable for providing incentives for green innovation and technological change (Sharpe and Lenton 2021; Pollitt et al. 2024). Complementary policies could include feebates in specific industries to expedite the shift of businesses and consumers toward energy-saving technologies, while easing the financial burden of such a change. A feebate is a type of environmental policy mechanism designed to encourage the production or adoption of more environmentally friendly goods. For example, the fee component can be imposed as an additional charge on polluting machines or vehicles, with proceeds used to fund rebates to those who invest in more efficient machines or vehicles.[48]

Impacts from carbon taxes on GDP will depend largely on how the government uses the revenues. Simulations using CPAT were conducted for a range of carbon price (CP) scenarios, from the low CP scenario to the Paris CP scenario.[49] These simulations should not be confused with the carbon tax discussion in the context of the CGE modeling, which examines the macroeconomic consequences of long-term structural change. CPAT provides insights for carbon pricing policy design based on short-term elasticities. In both the low and Paris CP scenarios, the net impact on growth is positive by 2030 (figure 27) and emissions would be lower than the REF scenario.[50] In the examples presented here, it is assumed that 40 percent of revenues are used to reduce labor taxation, 30 percent for public investments, and 30 percent for targeted cash transfers (the balanced scenario).[51] The ultimate effect on GDP will depend on

[44] 2017–22 average.

[45] The methodology used to estimate the TCP is based on Agnolucci et al. (2023). Refer World Bank (forthcoming, a) for methodological details.

[46] VAT deviations refer to VAT exemptions or reduced rates that apply specifically to certain fuels. The implications of Armenia's VAT threshold and/or exemptions to sectors with differential emissions intensity are not captured by this measure.

[47] Since 2015, there has been a feed-in tariff for solar power. Vulnerable groups pay lower tariffs, and utilities receive compensation for providing energy to them at a loss; the list of eligible households is approved by the government, which keeps a record of these allocations monthly (OECD 2018).

[48] In the EU, feebates have mainly been used and/or proposed in the transport sector, often tied to vehicle taxes and other regulations that seek to incentivize a shift to fuel-efficient vehicles.

[49] These correspond to the lower and upper ranges from High-Level Commission on Carbon Prices (2017). The CP is assumed to be introduced in 2024, with the low CP increasing from $14 to $20/tCO2 in 2030 and the Paris CP, from $72 to $83/tCO2 in 2030.

[50] Under the low CP scenario, index emissions would be reduced compared to the baseline but still (8%) higher than 2021 emissions. Under the Paris CP scenario, emissions would be 13.8% lower than 2021 levels, with indexed emissions of 86.2.

[51] Other options for revenue use available in CPAT are reducing corporate taxation and increasing current spending.

revenue use and will vary over time. Additional revenue could vary from 0.74 to 2.6 percent of GDP in 2034/2035, depending on carbon pricing levels (World Bank forthcoming, a).[52] While the carbon tax can be designed to further support growth, there may be distributional trade-offs. Although it is likely to have more impact in relative terms among the poorest deciles, targeted cash transfers could more than offset those losses, while the upper deciles could suffer from a reduction of the median income. Figure 28 provides an example under the low CP scenario (World Bank forthcoming, a).

Figure 27: GDP impact decomposition, Armenia (2030)

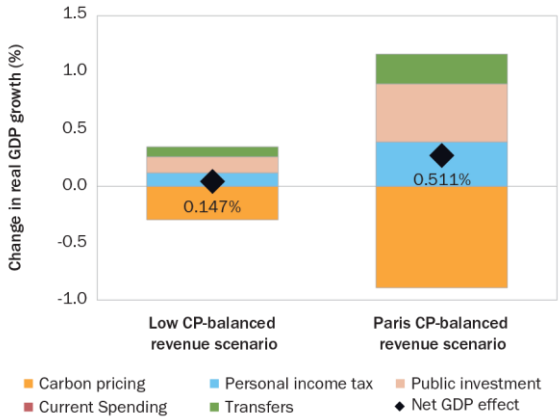
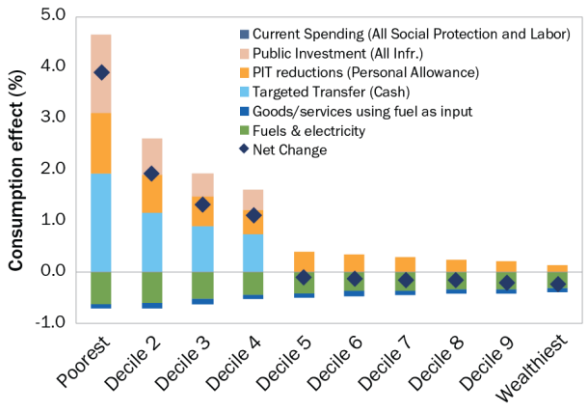


Figure 28: Relative median consumption effect in 2025, under the low CP–balanced revenue scenario



Source: World Bank forthcoming, a
Note: Cash transfers are directed to the bottom 40% of households, assuming a 90% *coverage rate* (percentage of targeted group that receives the transfer), and a 10% *leakage rate* (percentage of untargeted percentiles that receive transfers).

4.3.2. Policies to catalyze private investment

Armenia needs an estimated $8 billion for green investments (climate adaptation and mitigation in line with the NZS) during 2025–60.[53] More than 90 percent of the additional investments identified are required to decarbonize the economy, with a focus on RE (particularly solar power), energy efficiency in buildings and industry, and electrification of heating and transport (section 3.1). A significant part of this investment must come from the private sector, so providing the right incentives and regulatory framework will be key to mobilizing private investment at scale, for building resilience against climate-related risk and fostering green growth. This will also require developing an energy efficiency program that supports the growth of companies that can invest (for example, in building and retrofitting), making financing available to business owners to make such investments, introducing certification for some technologies, and providing support for energy audits.

A sustainable finance framework is essential to help Armenia scale up green financing, including from the private sector. In the past five years, around $100 million has been funneled into energy efficiency and RE projects through commercial banks and universal credit organization loans to small and medium-sized enterprises and households. Despite this, Armenia's banking sector has not fully tapped into green financing due to a lack of expertise and methodologies (CIVITTA 2022). Armenia needs to implement a sustainable finance framework, in alignment with the EU framework, which includes adopting a green taxonomy, an environmental, social and governance (ESG) disclosure framework, and a standard for corporate and sovereign thematic—such as green, social, sustainable, and sustainability-linked—bonds. Published in October 2023, the Central Bank of Armenia's Sustainable Finance

[52] The additional net revenues from the proposed policies could reach up to 0.60% of GDP in the low CP–balanced revenue scenario in the first year after reform, rising to 0.74% by 2034/2035. In contrast, the higher CP under the Paris CP-balanced revenue scenario could raise up to 2.6% of GDP in the first year after reform, falling slightly to 2.2% of GDP by 2034/2035, which is in line with the economy becoming less carbon-intensive.

[53] Expressed in discounted values and in 2015 $.

Roadmap comprises four pillars: facilitating capital to low-carbon activities in a risk-based, market-oriented, and sustainable manner; improving knowledge and market confidence and strengthening the enabling environment for climate finance; guiding financial market participants to embed ESG principles in business decisions; and raising awareness of sustainability risks and opportunities. Armenia could build its emissions reduction framework to leverage future carbon markets under the Paris Agreement.

If Armenia strengthens its PPP framework, it can use climate-focused PPPs to leverage private investment in low-carbon infrastructure. PPPs allow for risk-sharing between public and private partners in critical sectors, but without a strong institutional and legal framework, they can also add fiscal risks and costs. Although Armenia has a legal PPP framework, strengthening its institutional framework would help mitigate fiscal risks and ensure effective risk-sharing.[54] Although the country has experience with PPPs in RE (Masrik-1 solar photovoltaic plant), water, and transport (the South-Caucasian Railways and Armenia International Airports), it needs to increase its institutional capacity to implement PPPs going forward; improved planning and project management capacity, in particular, would increase the predictability of project delivery (CIVITTA 2022).[55] Emphasizing climate resilience in PPP parameters, terms, and conditions, and attracting green financing are also crucial. Armenia is enhancing its PPP framework to better manage liabilities and maintain fiscal sustainability. For projects with high economic but low financial viability, the government might consider hybrid PPP models that include viability gap funding to ensure feasibility.

International debt financing is crucial to enable private investment at scale for domestic clean energy resource development, which has implications for project development and risk allocation. To date, financing for solar and hydropower projects has primarily come from international financiers (in the form of sovereign or commercial financing), due to their ability to support larger-scale energy projects. This trend is expected to continue, with most financing for future projects likely to come from international banks and financial institutions, in line with what is observed globally. But foreign direct investment in private external financing in general has declined significantly over the past decade, while access to domestic finance in Armenia is moderate and masks important disparities (World Bank 2024b; World Bank forthcoming, a). Armenian banks are well positioned to provide at least a portion of the debt required for large projects at a cost-effective rate, but practitioners will need to adopt international best practices in project structuring, environmental and social risk management, and financial risk allocation to make projects bankable for this kind of debt financing.

The energy sector is well suited to attract private capital to close the mitigation investment gap. Armenia has a strong track record in attracting private capital in the energy sector, having attracted almost $2 billion over the last two decades**.** The country has demonstrated a capacity for private investment in its energy sector, particularly in areas such as RE (solar PV and hydroelectric power plants) and electricity network investments. The World Bank estimates that, between 2007 and 2019, 30 percent of total investment in the country (about $750 million or 0.5 percent of GDP per year) was public or publicly guaranteed, while the other 70 percent (about $1,750 million) was private capital.

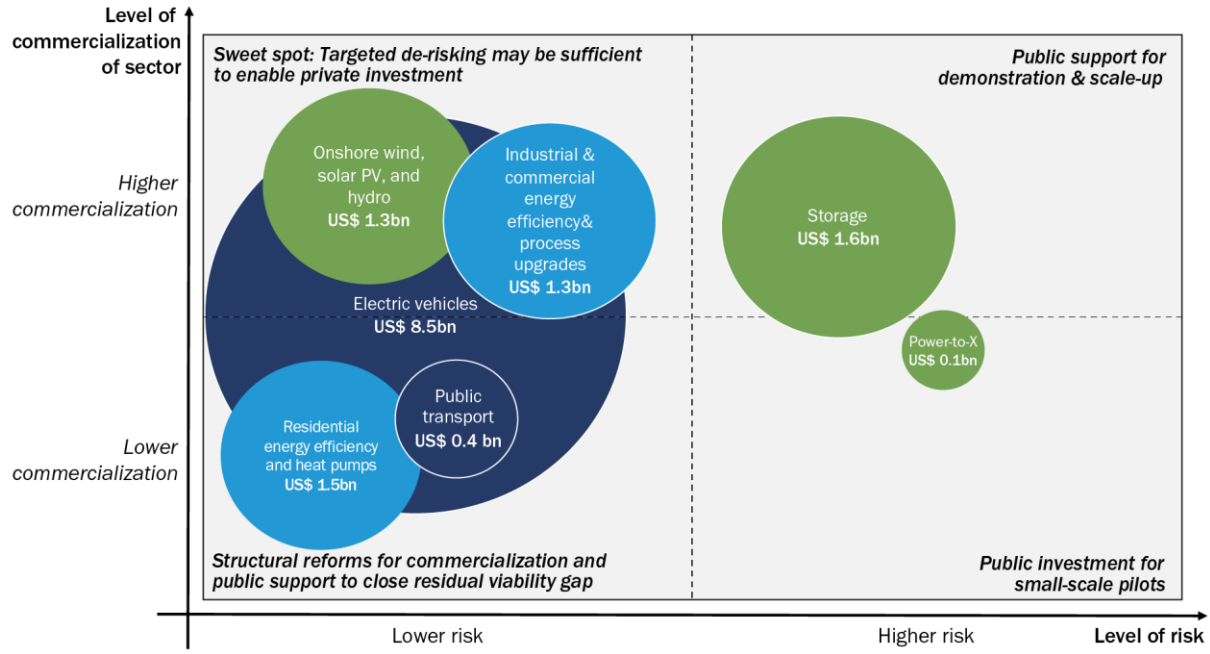
To attract private capital and close the climate mitigation investment gap, Armenia needs to continue to accelerate sectoral reforms, targeted support for PPPs, and demonstration and pilot investments. Figure 29 presents an indicative categorization of discounted incremental investment volumes—that is, the investment difference between the NZS and REF scenario. It shows that in the onshore wind, solar

[54] The PPP framework is based on a law adopted in 2019 and revised in 2021 to attract private finance in various sectors, including transport, RE, water, and waste management (World Bank 2022c; CIVITTA 2022).

[55] The government is exposed to around AMD 256 billion in broad contingent liabilities from PPAs in the energy sector and AMD 87 billion in contingent liabilities from a PPP in the water sector. Total contingent liabilities from PPAs and PPPs are at 6.92% of GDP, with PPPs in the transport sector being subject to significant material risk (contingent liabilities from South-Caucasian Railways and Armenia International Airports are 1.19% and 2.1% of GDP) (Schur et al. 2023).

PV, and hydro subsectors, the policy gap is small, and it would take just a few derisking interventions, such as off-take or non-commercial risk guarantees, to mobilize private investments. In public transport and residential energy efficiency, policies may need to combine structural sector reforms to improve the level of commercialization and public support to close the residual viability gap. In a third category of subsectors, which includes storage, public support for demonstration and scale-up could help create the conditions for scalable private investment. Finally, in *power-to-X* subsectors, technology development is still nascent, and public investment in demonstration projects would be a precondition for further developing power-to-X in the country. Overall, when including private road transport and freight, the discounted investment volumes in highly commercialized sectors add up to about $4.1 billion, or 70 percent of the total discounted investment of $6 billion for mitigation until 2060.

Figure 29: Discounted investment gap until 2060 for selected subsectors in the energy system, with indicative categorization by level of risk and commercialization in Armenia



Source: World Bank staff calculations, based on CompactPRIMES modeling.
Notes: Rail ($0.01 billion) and freight transport ($0.4 billion) are omitted here because of the already high level of private investment.

The private sector in Armenia has a triple role to play in supporting adaptation: providing finance, adapting its own operations, and offering goods and services to help others adapt. This is particularly clear in the water sector. First, banks can collaborate with IFIs and the government to fund water efficiency, supported by international donors and blended finance. Investment mechanisms vary, and can involve private, PPP, or public funding, depending on the infrastructure's purpose. Second, the government can encourage companies to enhance their operations through time-bound and targeted subsidies or tax breaks. This includes incentives for large water users to build reservoirs, upgrade water transport infrastructure to decrease water losses, and adopt efficient technologies; and incentives for individual farmers and other small users to implement drip irrigation or CSA. Third, widespread adoption of sustainable practices could foster a local market for related goods and services. Firms can supply locally produced and imported equipment to farmers, including pipes and automated systems, as well as maintenance and training services. Armenia can use this opportunity to develop sectors such as PV-based irrigation and an Internet of Things for more efficient and value-added agriculture.

Coordinated policy reforms can have a material impact on the availability of climate finance in Armenia. Boosting private capital mobilization for climate requires a series of targeted policies to

address different gaps. Together, these policy reforms can have a material impact on the availability of climate finance in Armenia. First, having a clear green transition roadmap based on a strong regulatory framework reduces uncertainty and builds investor confidence, leading to increased private capital inflows. Second, implementing market-based mechanisms such as carbon pricing creates financial incentives to reduce emissions and generate additional revenue that can be reinvested in climate projects. Third, instruments such as PPPs and blended finance allow for risk-sharing between the public and private sectors. With the help of IFIs and international climate funds, Armenia can use these instruments to leverage public investment to attract significantly higher resources from domestic and foreign private investors. Fourth, implementing a sustainable finance framework aligned with EU regulation will increase transparency and accountability, making Armenia more attractive to responsible investors. Overall, these policies would create a more favorable investment environment for climate finance, attract a diverse range of investors, and significantly increase the availability of funds for climate mitigation and adaptation projects in Armenia.

Finally, more data and knowledge on climate change impacts can help support access to the new Loss and Damage Fund. A landmark decision at the 28th United Nations climate change conference, COP28, was to operationalize a fund for responding to loss and damage.[56] The board of the fund held its second meeting in July 2024, and will further develop the fund's operational and implementation parameters —such as eligibility and activities—in line with the governing instrument that was contained in the COP28 decision. Depending on these parameters, Armenia might be able to access some of this funding to respond to climate change impacts. Continuing to develop data about and knowledge of climate change impacts on the country will be key to requesting support from this kind of fund.

4.4. Inclusive transition

4.4.1. Impacts of climate change and decarbonization on poverty

The direct impacts of climate change on yields and labor productivity under a hot/dry scenario could increase poverty by 0.6–0.9 pp compared to the REF scenario. In 2030, under the REF scenario assumptions, poverty is reduced to 15.5 percent of the total population, a 9.2 pp decrease compared to the 2022 poverty rate.[57] This CCDR explores several scenarios to assess possible climate change impacts on poverty in 2030. Using the extreme assumption that agriculture workers would bear 100 percent of yield and labor productivity losses due to climate change through reduced agriculture income (assuming they do not benefit from an increase in food prices), poverty could increase to 16.5 percent of the population. This is a 1 pp increase compared to the REF scenario, but the effect would be concentrated in rural areas, where the poverty rate would increase by 3pp against 0.3pp in urban areas. In absolute numbers, most of the people falling into poverty because of direct climate change impacts would be in Armavir, Vayots Dzor, Shirak, and Ararat, where the population is more reliant on agriculture revenues. On the other hand, in the CGE model, the hot/dry impacts of climate change would increase wages in agriculture due to higher food prices, and losses would be distributed to all workers through general equilibrium effects, so the total impacts would only result in a 0.8 pp increase in the poverty rate, with a more uniform distribution between urban and rural populations. The reality might be between these two extremes, as farmers with limited voice and political power could bear a higher share of climate impacts than those able to pass through part of their yield losses to their clients or landowners.

When adding the impact of climate change on food prices, poverty could increase by 2.7 pp by 2030 compared to the REF scenario. In the CGE model, the impact of climate change on agriculture under a

[56] The World Bank was invited, on an interim basis and subject to conditions, to act as the host for the fund secretariat and trustee. Following approval by its Board of Executive Directors, the World Bank confirmed to the COP28 Presidency in June 2024 that it is willing and able to meet the stipulated conditions. In August 2024, it submitted relevant financial intermediary funds documentation, including a hosting agreement, to the board of the Loss and Damage Fund.

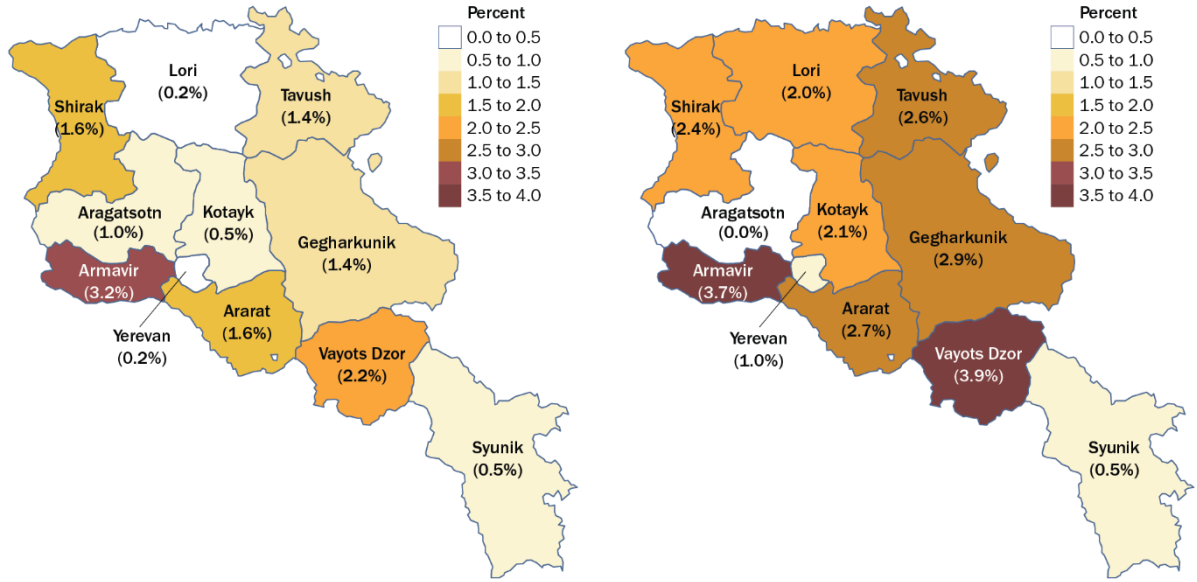
[57] Poverty headcount represents the proportion of the population that is below the official poverty line of AMD 52,883 per person per month at 2022 prices, adjusted for adult equivalence and absenteeism.

hot/dry scenario results in a 6 percent increase in food prices compared to the baseline in 2030. This in turns increases poverty by 2.7 pp compared to the baseline when added to the impacts of climate change on wages and employment from the CGE. While at the national level, 2 percent of the population would be pushed into poverty by 2030, in Vayots Dzor, the figure would be nearer 4 percent due to a combination of climate impacts on employment, wages, and food prices (figure 30). The poverty gap also increases by 0.6 pp compared to the REF scenario.

Figure 30: Increase in poverty (as a percentage of marz population) under a dry/hot scenario, by marz, compared to REF scenario, 2030

a) Direct impacts of climate change on agriculture

b) Indirect impacts due to wages change and increased food prices (CGE model



Source: World Bank staff calculations, based on CCDR macro scenario information and data from ARMSTAT 2023
Notes: Panel a considers impacts on labor productivity and agriculture yields. Panel b captures general equilibrium effects of the hot/dry scenario from the CGE model, including the food price difference between the REF and dry/hot macroeconomic scenarios.

Limited asset ownership could increase women's vulnerability to, and reduce their ability to bounce back from, climate shocks. In Armenia, most assets, such as land, dwellings, or large cattle are owned by men. This is concerning because around 70 percent of loans require collateral—a figure that has remained unchanged over time—which leaves women with limited access to financial resources to invest in climate-resilient infrastructure, equipment, or practices.

Depending on the impact of the transition on energy prices, the low-carbon transition could increase the poverty rate by 0.5–3.3 pp in 2030 compared to the REF scenario but would reduce inequality. The impact of the low-carbon transition on employment and wages, combined with the redistribution of tax revenues, only increases poverty by 0.4 pp in 2030 compared to the REF scenario, or 0.5 pp when adding the increase in energy prices required to switch energy technologies. In this scenario, the poverty gap goes down compared to the REF scenario (from 2.6 to 2.5 percent), poverty severity goes down from 0.67 to 0.59 percent, and the Gini coefficient goes down from 24.7 to 24.1.[58] In contrast, when considering the impact of the carbon tax required to reach net zero in the CGE model on energy prices,

[58] The *poverty gap* is the average shortfall of the incomes of the poor as a percentage of the poverty line. *Poverty severity* is the square of the poverty gap, and gives more weight to individuals who are further below the poverty line, emphasizing the severity of poverty. The *Gini coefficient* measures overall income inequality, with values closer to 0 indicating more equality, and values closer to 100 indicating more inequality.

poverty could increase by 3.3 pp compared to the REF scenario and the poverty gap by 0.5 pp; however, the Gini coefficient would go down even further to 23.8.

4.4.2. Reducing the poverty and distributional implications of physical and transition impacts

Spatially targeting adaptation investments can benefit the poor and most vulnerable. Different regions in Armenia are exposed to different severities of climate impacts, as some have high poverty levels, lower access to infrastructure services, and high impact of floods or water availability for irrigation. Investment in irrigation efficiency, CSA, and resilient infrastructure can be targeted at marzes with higher levels of poverty and lower access to basic services. Priorities include the Ararat valley for water efficiency, Shirak and Tavush for land restoration, Armavir and Shirak for CSA, and Lori, Tavush, Syunik, and Vayots Dzor for resilient roads and public buildings. Importantly, CSA can also offset the negative impacts of the low-carbon transition on farmers, as it contributes to increasing yields and revenues while reducing emissions from agriculture.

Armenia's SP system will play an important role during the transition and in response to climate shocks, and must be prepared to expand outreach in response to shocks. During the COVID-19 pandemic, the government protected the financing of regular programs and increased the SP budget, but this was not commensurate with the increase in the number of social assistance beneficiaries (horizontal scale-up). As a result, many of the poor and vulnerable—particularly those in the informal sector—were left without support. This raises questions about the system's capacity to identify and reach out to the most vulnerable families and individuals who are not already enrolled in the system and need immediate assistance when impacted by large-scale shocks. Focusing on vertical scale-up might reinforce the bias toward groups that are already served by SP systems, which may not include all the vulnerable or those most affected by the shock.[59] Recent reforms to the vulnerability assessment methodology are expected to improve targeting under the Family Benefits Program. To build adaptive SP to enhance poor and vulnerable households' resilience to shocks, the system must also include protection against unemployment and employment injury.[60]

4.4.3. Transition impacts on jobs and workers

Building up green skills and activating the labor force to be involved in green jobs can offset some transition impacts and increase resilience and welfare, ensuring an inclusive green economy. Historically, rural earnings growth and occupational and spatial mobility have been highly constrained in Armenia. To implement green growth, Armenia must strengthen forest and landscape management, manage pollution on circular economy principles, innovate with alternative energy and energy efficiency measures, and adopt a multisectoral, efficient approach to sustainable development. This fundamentally needs to be supported by strengthening human capital with green skills and a more inclusive and efficient labor market.

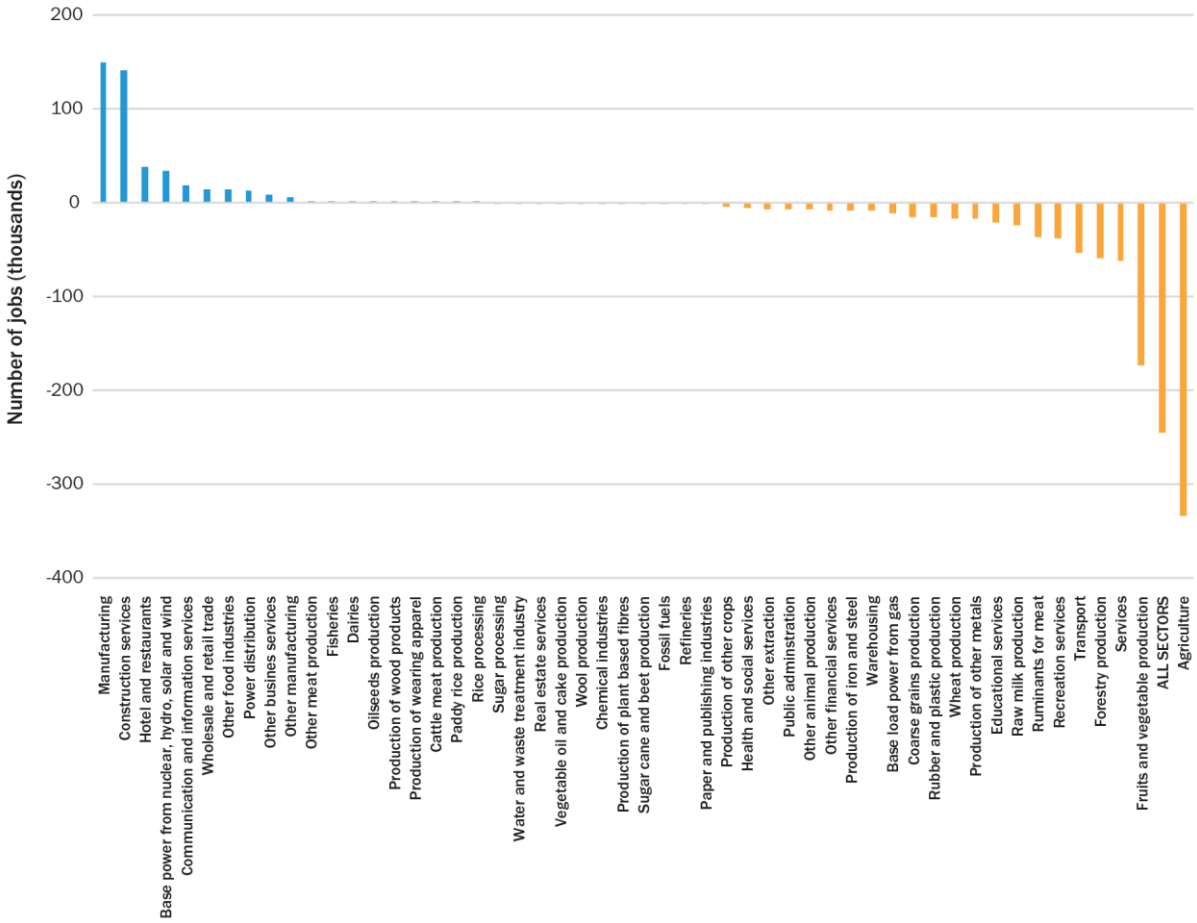
While the aggregate employment impacts of the transition will be modest and vary over time, there will be significant employment shifts across sectors. Modeling results indicate that aggregate employment in all sectors declines by 1.1 percent (approximately 245,000 jobs) under the NZS. These relatively small aggregate employment impacts mask larger shifts across sectors. The losses are primarily in agriculture, and the gains largely in manufacturing and services. The main losses in the agriculture sector are in fruit and vegetable, meat, milk, and grain production. Forestry also declines, as do recreation and transport in the services sector. The gain in jobs is mostly in the manufacturing sector (food processing), services (construction, hotels, restaurants, and ICT), and RE (hydropower,

[59] Survey data suggest that the response to the COVID-19 shock was effective but not efficient. While the poverty rate and poverty gap did not increase, the BCR of social assistance benefits—measured as the poverty gap reduction, in local currency units, for each unit spent on the social program—dropped. But it is important to note that the efficiency lens needs to be applied to shock-response measures with caution. In most cases, a no-regrets approach (anticipatory action) is more suitable to shock response interventions.

[60] Unemployment insurance was removed from the SP system in 2013 and replaced with a case-by-case cash support system for unemployed jobseekers.

solar, and wind) (figure 31). These sectoral shifts will have implications for relative skills demand, although the green transition tends to also be associated with a shift toward higher-skilled occupations *within* sectors.

Figure 31: Cumulative employment change through 2040: NZS relative to REF scenario



Source: World Bank staff calculations, based on the CGE results.

Armenia's low-carbon transition has the potential to create jobs, especially in tradeable sectors, such as manufacturing, where green technologies can boost competitiveness and employment. The country's textile exports, with their lower GHG emissions, have a competitive edge in eco-conscious markets. Armenia's exemption from the EU's CBAM for certain exports, as discussed in chapter 1, could increase demand for its mining products, which are vital for RE technologies. The services sector, particularly ICT, could grow by providing essential environmental services. Armenia's significant export growth of climate-critical minerals, such as copper, aligns with the global shift toward sustainable energy. But capitalizing on these opportunities will necessitate enhanced environmental regulations and human capital development to support the green transition and reduce carbon intensity in production (see appendix).

4.5. Aligning climate and development policies

A transition to a green economy requires consistency and coordination across sectors, and both the Ministry of Finance and Central Bank have central roles to play. Sectoral and macroeconomic policies and actions must be coordinated and consistent—for example, power sector policies must consider decarbonization and electrification in energy-use sectors—with the magnitude of existing and expected challenges to achieving development objectives and with financing and implementation capacity.

Promising interventions include investing in key clean energy technologies with consistent cost declines, undertaking climate budget tagging and climate-informed budgeting, adopting a green taxonomy and sustainable finance framework, introducing central bank policies to reduce the value of polluting collateral, and enhancing climate-related financial risk disclosure (Mealy et al. 2023; Sharpe and Lenton 2021).

Although Armenia has made significant progress in developing its institutional framework for climate change, it needs to develop a risk management approach that balances socioeconomic development and long-term fiscal sustainability objectives (IMF 2022). This includes clarifying risk assignment, using risk retention and transfer instruments, and ensuring robust investment planning, prioritization, and the realization of risk reduction investments. To improve fiscal risk management, the country can establish a fiscal risk council to create fiscal space and guide the prioritization of adaptation investments. This will ensure Armenia's adaptation investment program is fully embedded in its fiscal framework. It can also develop a climate risk assignment framework to identify which risks will be borne by the national government and how it will share risks with subnational governments, SOEs, private firms, and individuals. It can direct public funds into adaptation investments by developing adaptation investment plans that reflect the risk assignment process for all key sectors, engaging the private sector, and facilitating access to international financing. Finally, developing and piloting a tracking methodology for the national and subnational governments and SOEs to plan and budget climate investments will allow the country to monitor and evaluate progress.

Well-designed and properly sequenced structural reforms can help reduce transition costs, accelerate progress toward net zero, and ensure a just transition. Structural reforms that promote labor market flexibility, product market competition, and well-functioning financial markets can facilitate the green transition in Armenia. Reforming labor market institutions and passing employment protection legislation to increase labor market flexibility and building human capital through green skills training and support for displaced workers to reskill and upskill can give workers the resources they need to move to green jobs. The latter is particularly pertinent, given Armenia’s mismatch between skills supplied and labor market demand, so adapting the curriculum now is a timely opportunity. Competition can create a market environment that encourages innovation, lowers costs, and increases the availability of green technologies and services. Measures could include making it easier to start and operate a green business, levelling the playing field by making it easier for green companies to compete, and targeting support for companies working on green technologies. The government could conduct cost-benefit analyses before granting any fiscal incentives to encourage economywide decarbonization, regularly review fiscal incentives to ensure that expenditure is effective and efficient, and provide financial support based on competitive mechanisms.

Financial markets can support the transition by mobilizing and allocating capital to sustainable projects and technologies. Developing both a sustainable finance framework and the country’s capital markets is vital. The government’s structural reform priorities—such as boosting labor force participation among the vulnerable population, upgrading the insolvency framework to promote firm entry and exit, and encouraging diversification in the country’s export basket and markets—can also promote the transition (IMF 2024).

5. From assessment to action

To navigate the transition, Armenia will have to pay due attention to prioritizing interventions. The recommendations in table 3 are prioritized in terms of impact and urgency, considering their decarbonization and resilience impact, their potential to reduce macroeconomic and social risks, and/or their potential to strengthen human capital. In terms of urgency, short-term actions, including no-regret measures that lead to aggregate economic gains and those that cannot be postponed despite their additional costs because, for example, of the need to avoid lock-in or stranded assets, are prioritized over long-term interventions that can be delayed at limited to no cost—for example, due to the expected decline in technology costs. Policy recommendations are also screened in terms of institutional readiness for implementation, providing an indication of whether the current policy and institutional frameworks, human capital stocks, fiscal capacities, and enabling private investment environment can support implementation or whether actions are needed to strengthen these.

The report advocates first-best solutions of fully pricing all fossil fuels to account for their environmental and social costs through explicit carbon pricing and correcting other pricing mechanisms like water tariffs. This is in line with recent research indicating that proper pricing and regulation are essential prerequisites for other green incentives and investments to effectively support emissions reduction. In this regard, the phasing out of any remaining hydrocarbon subsidies could be complemented by the introduction of an explicit upstream carbon tax and scaling up existing excises on fuels. As these reforms often have an impact on certain industries and population groups, part of the fiscal proceedings could be redirected to compensatory measures.

In addition, while these changes are being designed and implemented, the report also proposes a set of incentives that would stimulate investments in low carbon sectors. The term "incentives" in this report encompasses a variety of economic instruments which aim to stimulate investments to achieve multiple objectives including sustainable development. These incentives are not limited to, nor do they primarily suggest, tax exemptions or new tax incentives. The approach emphasizes financial incentives that aim to correct market distortions by appropriately pricing externalities, such as pollution, that are currently not reflected in the market. It is crucial for these incentives to be specific, time-bound, and targeted, and to be analyzed in the context of the government's tax policy strategy. Examples include feed-in tariffs, subsidies, and tax exemptions for renewable energy installations, electric vehicles, and retrofitting building. Additionally, regulations and standards can create a more favorable environment for sustainable practices, such as policies to enhance public transportation, which create positive externalities by reducing congestion and air pollution. Armenia already has several measures in place to encourage a green transition. The report's recommendations are intended to complement and strengthen these existing measures, ensuring they are effective and aligned with the overall policy objectives.

Table 3: Summary of CCDR policy recommendations for Armenia

High-level objective	Priority policy actions	Lead agency, ministry, or stakeholder	Indicators for implementation	Key implementation barriers	Priority	Sector	Policy type
Raise the ambition of its 2030 NDC mitigation target	**SHORT TERM** Raise the ambition level of the 2030 NDC target to 65% reduction compared to 1990 to signal climate mitigation ambition and readiness for business to investors in climate-friendly industries and put the country on track to meeting its 2050 objectives	Ministry of Environment (MoE)	Meeting NDC 2030 emissions reduction target	Political	High	Government	Mitigation
Plan and implement the green transition	**SHORT TERM** Develop and adopt the green economy strategy announced in 2022 Sequence each of the green transition plan components to reinforce the other toward decarbonization and in a way that reduces transition risks for vulnerable groups **MEDIUM TERM** Progressively strengthen Ministry of Territorial Administration and Infrastructure (MOTAI) institutional capabilities to prepare capital programs/projects aligned with strategic climate mitigation and adaptation objectives and results Strengthen institutional collaboration across MoEc, Ministry of Finance (MoF), prime minister's office, and line agencies to prioritize, appraise, and resource climate action-aligned public infrastructure projects, particularly through the mechanism for the Investment Committee (under the prevailing PIM framework) Mobilize and allocate enough budget to each sector for implementing the plan Implement the different components of the green transition plan in line with designed sequencing	MoF MoE Ministry of Economy (MoEc) MOTAI Public Services Regulatory Commission	Adoption of integrated green transition plan that includes needed infrastructure investments, pricing policies, and economic policies, with sequencing considerations	Institutional capacity	High	Government	Mitigation and adaptation
Institutionalize monitoring of climate-related risks for enhanced management of climate risks and policy design for mitigation, adaptation, and resilience	**SHORT TERM** Better understand and analyze the climate-related physical, transition, and contingent liabilities risks Better quantify estimated fiscal risks from climate change in annual fiscal risk statements and integrate nature and ecosystems into macroeconomic frameworks Design climate and disaster risk and stress test requirements for key private sector actors **MEDIUM TERM** Include contingent liabilities from natural disasters and environmental shocks in the planning and budgeting process Integrate a sector-by-sector understanding of climate risk, adaptation plans, and investment needs in the budget process Institute climate and disaster risk stress-testing requirements in regulations for banks, insurers, and large investors	MoF MoE Ministry of Interior MoEc Central Bank of Armenia Private sector (local banks)	Elaboration of macroeconomic modeling and analysis of climate-related physical, transition, and contingent liabilities Adoption of risk management strategy that includes prioritized investments (MoF) Revision of the budget process to include the risk management strategy and links to PIM Elaboration of annual fiscal risk statements with more quantifiable estimates of fiscal risks	Institutional capacity	High	Government Financial	Adaptation and mitigation

High-level objective	Priority policy actions	Lead agency, ministry, or stakeholder	Indicators for implementation	Key implementation barriers	Priority	Sector	Policy type
	Promote economic resilience to climate shocks, including by building fiscal buffers and support targeted SP programs		from disaster and climate risk Adoption of climate and disaster risk and stress test requirements by the private sector				
Promote green growth through structural reforms	**SHORT TERM** Raise awareness of mechanisms for improving energy efficiency through information campaigns and benchmarking reports Extend market energy audits Analyze the production and export potential of green services and products Design reforms to promote labor mobility, up-skilling, education, and training for the green economy **MEDIUM TERM** Enhance the business environment to allow for the emergence of young innovative firms Support research and development initiatives and create technology clusters to drive innovation Boost green technology adoption and managerial practices through a combination of soft and financial support Strengthen local supply chains to reduce dependency on distant suppliers Enhance infrastructure quality and climate resilience to align with green standards Adopt international standards to support trade including building emissions measurement, reporting and verification quality infrastructure, using tools such as e-Phyto for sanitary and phytosanitary controls, and expanding capacity-building programs for firms to meet international green certification demands Expand leasing and other financial instruments that can promote green growth Enact reforms to promote labor mobility, up-skilling, education, and training for the green economy	MoF MoEc MoE Ministry of Education, Science, Culture, and Sport Ministry of Labor and Social Affairs		Institutional capacity	High	Government Education sector	Mitigation
Adopt appropriate carbon pricing	**MEDIUM TERM** Design pricing policies, revise environmental taxes (including air pollution tax) and consider introducing an explicit carbon price through an upstream carbon tax as part of the policy mix and by scaling up existing fossil fuel excises. Design social transfers to compensate the negative impacts of the carbon tax on vulnerable households	MoF Ministry of Labor and Social Affairs	Increase in price of carbon Adoption of social transfers using the revenues from the higher carbon pricing	Changes in pricing policies require buy-in from stakeholders, including public and private financial institutions		Government	Mitigation

High-level objective	Priority policy actions	Lead agency, ministry, or stakeholder	Indicators for implementation	Key implementation barriers	Priority	Sector	Policy type
	As part of the policy mix, consider targeted use of feebates to incentivize firms to adopt emission-saving technologies						
Enable private capital mobilization	**SHORT TERM** Strengthen institutional capacity to implement PPPs Improve the PPP framework to better monitor and manage contingent liabilities, maintain fiscal sustainability and ease implementation, and transition out of PPP modalities for the scale-up of wind, solar, storage, and other clean energy projects that can be supported through standardized mechanisms Follow up on the Sustainable Finance Roadmap published in 2023 and adopt a Sustainable Finance Framework aligned with EU regulations Adopt a green taxonomy, an ESG disclosure framework for financial and nonfinancial companies, and a standard for issuing thematic corporate and sovereign bonds Work with local banks, international donors, and IFIs to create concessional credit lines for private investment in adaptation **MEDIUM TERM** Build local financial sector capacity for project structuring, environmental and social risk management, and financial risk allocation, following international best practices Create local capacity for issuing key performance indicator-based debt, such as sustainability-linked bonds, to create investment opportunities for firms willing to improve their environmental performance	MoF MoEc Central Bank of Armenia Private sector (local banks)	Number of PPPs implemented Adoption of green taxonomy (yes/no) Adoption of disclosure standards (yes/no) Number and size of credit lines created Adoption of a sustainable financing framework (yes/no)	Changes in financial regulation require buy-in from key stakeholders, including public and private financial institutions	High	Financial	Adaptation and mitigation
Scale up variable RE generation, accompanied by enabling investments in the transmission grid and battery storage	**SHORT TERM** Review and revise targets for solar PV development (aligned with the 2040 Energy Sector Development Strategy [ESDS] activities 1.6–1.11 and the Programme on Energy Saving and Renewable Energy [ESRE] for 2022–30 measures 2.31 and 3.1.43) to achieve at least 1 GW by 2030, 2.3 GW by 2035, and 4 GW by 2040 Implement pilot wind power project (ESDS activity 1.13) and develop roadmap to achieve 0.5 GW of wind by 2040 Develop and implement a national transmission grid modernization program and review tariff methodology for private distribution grid investments with a view to increase investment sufficiently to absorb over 1.1 GW of variable RE integration by 2030 and 2.6 GW by 2035 (ESDS activity 2) Pilot and scale up battery solutions in the grid and building level to achieve at least 1.8 GW of battery storage by 2030 to increase shares of solar PV (ESRE measures 2.32 and 3.1.39–42) **MEDIUM TERM**	MOTAI Public Services Regulatory Commission Renewable Resources and Energy Efficiency Fund MoF MoEc Private sector	GW of solar PV installed GW of wind power installed Variable RE absorption capacity of the power grid GW of battery solutions installed Ability of energy SOEs to mobilize commercial financing (yes/no) Policy framework for land use for solar PV (yes/no)	Limited financial attractiveness of investments on a merchant basis, and cumbersome and slow administrative processes for state-supported investment	High	Energy	Mitigation

High-level objective	Priority policy actions	Lead agency, ministry, or stakeholder	Indicators for implementation	Key implementation barriers	Priority	Sector	Policy type
	Transition energy SOEs to commercial financing to enable scale-up of grid investments without sovereign guarantees Develop a land-use policy for solar PV to create synergies with agriculture where possible and avoid competition with food and feed crops						
Invest in publicly funded infrastructure and strengthen policy frameworks for clean transport	**SHORT TERM** Leverage public procurement for electrifying the government vehicle fleet, with adequate charging infrastructure (ESRE measure 3.3.2.62) Leverage modern concession models for public transport to accelerate the uptake of e-buses by mobilizing private capital Introduce regulatory requirements and/or carbon-differentiated tax schemes targeting the early electrification of company fleets and other high-use vehicles (taxis, buses, shared vehicles, etc.) (ESRE measure 3.3.2.62) Roll out charging infrastructure and review incentives in the short term for electric mobility to achieve 42,000 electric vehicles by 2030, 230,000 by 2035 and 550,000 by 2040. Raise local pollutant emission standards (Euro 6) for both new vehicles and second-hand imports and, in the short-term, provide incentives for replacing old vehicles Introduce fuel efficiency standards for new vehicles and second-hand vehicle imports (CO2/km) differentiated by vehicle segments and gradually reduce total petroleum consumption in passenger transport Expand the public road transport network to absorb 22% of total passenger transport (4,782 million person-kilometers, up 22% on 2020) and rail network to absorb 17% of total freight (1,257 million ton-kilometers, up 26% on 2020) by 2030 Introduce regulatory requirements on off-street charging infrastructure availability: for public garages, new/renovated private garages, and pre-cabling in new/renovated buildings to secure the 'right to plug' **MEDIUM TERM** Move from current VAT exemptions into revenue-generating interventions such as carbon-differentiated vehicle taxation or self-funding feebates schemes Periodically adjust the feebate schemes in line with fuel efficiency improvements and electric vehicle uptake to maintain market signals and the program's financial sustainability Adjust public financial support to publicly available charging infrastructure to target underserved areas, such as rural and lower-income areas, and complement this with properly designed concession tenders to facilitate cross-subsidization by bundling multiple locations Build up capacity for e-waste management related to electric vehicles	MOTAI Public Services Regulatory Commission MoF MoEc MoE Consumers	Number of electric vehicles Petroleum consumption in passenger transport Transport activity absorbed by public road transport and rail networks	Limited charging infrastructure for electric mobility Underpricing of natural gas for transport Limited investment budget for rail network	High	Transport	Mitigation

High-level objective	Priority policy actions	Lead agency, ministry, or stakeholder	Indicators for implementation	Key implementation barriers	Priority	Sector	Policy type
Pilot programs for clean gas and green hydrogen (power-to-X) for use in hard-to-abate applications, but carefully manage the risk of stranded assets	**SHORT TERM** Improve integrated energy system planning capacity in the MOTAI to anticipate transition needs and risks Develop regulations and standards to prepare for upgrading of gas distribution infrastructure to accommodate increasing shares of blended clean gases including biomethane and synthetic methane **MEDIUM TERM** Initiate selected pilot investments for clean gas and green hydrogen (power-to-X) for use in hard-to-abate applications	MOTAI Public Services Regulatory Commission MoF MoEc Renewable Resources an Energy Efficiency Fund (R2E2) Private sector	Regular publication of integrated energy and climate mitigation plans (every 3–4 years) Regulations in place for clean gas blending in the gas grid (yes/no) Pilot projects for power-to-X capacity installed by 2030 (at least 2)	Limited staffing resources in the MOTAI Lack of prior experience in Armenia with power-to-X or similar applications	Moderate	Energy	Mitigation
Continue the transition to competitive energy markets, while providing targeted protection of vulnerable consumers	**SHORT TERM** Continue the gradual liberalization of electricity market (ESDS activities 4.1 and 4.2) to reach near-100% in the share of producers and consumers that are participating in the liberalized electricity market Gradually but steadily increase end-consumer natural gas prices to international benchmarks to incentivize the shift from natural gas to electricity Identify energy-vulnerable consumers and pursue targeted SP measures in parallel with price reforms, combined with a broader strengthening of the SP system (including data, capacity, targeting, etc.) (ESDS activity 4.4), to ensure targeted social protection support reaches 100% of energy-vulnerable consumers by 2030 **MEDIUM TERM** Continue the gradual price reforms for carbon and natural gas	MOTAI Public Services Regulatory Commission Ministry of Labor and Social Affairs MoF MoEc	Share of producers and consumers that are participating in the liberalized electricity market (near-100 percent by 2030) Approved definition of energy-vulnerable consumers (yes/no) Coverage of energy-vulnerable consumers with targeted SP (%)	Limited budget and capacity to reach and protect vulnerable consumers limits scope for price increases	High	Economy-wide	Mitigation
Develop programs to scale up energy efficiency and electrification in the industry, commerce, buildings, and digital sectors	**SHORT TERM** Set up a national program for building energy efficiency (ESDS activity 8.2 and ESRE measure 3.2.46) and reach an annual rate of building energy efficiency renovations of 3% per year by 2030 Enhance energy efficiency standards for buildings, appliances, and industry (ESDS activities 8.1, 8.2, 8.4 and ESRE measures 3.3.50 and 3.3.54) Incentivize the upgrade of digital connectivity infrastructure from copper-based to low-energy fiberoptic connectivity networks **MEDIUM TERM** Provide financial assistance to the private sector for building energy efficiency, including electrification of heating through heat pumps Develop a roadmap to leverage clean energy potential in Armenia to attract private investment in green data infrastructure	MOTAI Urban Development Committee Renewable Resources and Energy Efficiency Fund MoF MoEc	Final energy consumption per unit of GDP in kilowatt hours per $, indexed to 2020 Rate of building energy efficiency renovations per year (%) Roadmap for private green data investment (yes/no)	Lack of building standard and regulation enforcement Limited financial attractiveness of investments in energy efficiency due to underpricing of natural gas and carbon emissions	High	Industry and commerce Buildings Digital Energy Crosscutting	Mitigation

High-level objective	Priority policy actions	Lead agency, ministry, or stakeholder	Indicators for implementation	Key implementation barriers	Priority	Sector	Policy type
Increase water storage and efficiency	**SHORT TERM** Rehabilitate and modernize water conveyance infrastructure, on-farm systems, and pumping stations serving at least 50,000 hectares of irrigated land Invest in three high-performing reservoirs to increase irrigated areas Design a masterplan for new storage investments **MEDIUM TERM** Rehabilitate and modernize water conveyance infrastructure, on-farm systems, and pumping stations serving the remaining 150,000 hectares of irrigated land Invest in new reservoirs following the new masterplan, using a phased approach that depends on future climate change impacts	MOTAI Water Committee	Hectares of agriculture land served by modernized conveyance canals and pumping stations Increased water productivity (kg/cbm) Master plan for storage (yes/no) Additional storage available (cbm)	Lack of funding for infrastructure maintenance and rehabilitation	High	Water	Adaptation
Improve water resource management	**SHORT TERM** Allocate more resources to support hydrological, agrometeorological, climate, and meteorological monitoring using geographic information systems and remote sensing tools Engage stakeholders, including local communities, in water resource management decision-making Encourage public participation and raise awareness about the importance of water conservation to improve water use efficiency Carry out a comprehensive re-evaluation of the volume of usable groundwater resources in the Ararat Artesian Basin Ensure illegal water users in the basin (mainly for municipal and irrigation purposes) obtain water use permits and revise the permit and fine system **MEDIUM TERM** Strengthen the institutional capacities of the Water Committee, the Water Supply Agency, and WUAs Create more favorable enabling environments to improve efficiency and implement environmental and rural development policies Develop and implement an adequate tariff methodology for water supply systems and irrigation; review and update existing (outdated) irrigation norms; and bring in metering for transition to a two-part irrigation tariff, based on area and volumes Revise water-use permits based on the updated assessment of the volume of usable groundwater resources in the Ararat valley Continue placing efforts to support transboundary cooperation with all neighboring countries and promote transboundary water management agreements, especially for shared rivers and basins, to address water resource challenges collaboratively, including by promoting technical country-to-country technical water resource management exchanges among public sector staff	MOTAI Water Committee WUAs Water Supply Agency MoE	Resources allocated to hydrological, agrometeorological, climate, and meteorological monitoring Center established for integrated water and climate planning Number of workshops to engage users in water resource management Re-evaluation of the volume of usable groundwater in Ararat basin (yes/no) New tariff methodology for irrigation (yes/no) New irrigation norms (yes/no) New water-use permit allocation	Limited capacity of government and WUAs	High	Water	Adaptation

High-level objective	Priority policy actions	Lead agency, ministry, or stakeholder	Indicators for implementation	Key implementation barriers	Priority	Sector	Policy type
Increase agricultural productivity and resilience with climate smart agriculture	**SHORT TERM** Record CSA activities in the 2024 agriculture census Provide incentives and training for farmers in using drip irrigation and adopting CSA practices Bring the early warning system in agriculture to full functionality **MEDIUM TERM** Modernize another 150,000 hectares with modern on-farm irrigation systems and expand irrigation Progressively introduce and then mainstream climate-resilient crop production, energy and water saving technologies, waste management, circularity, and regenerative agriculture	MoEc Water Committee WUAs	Hectares of agriculture land with modern on-farm irrigation systems Fully functional early warning system in agriculture Number of farmers trained in CSA practices	Limited financial attractiveness of investments in modern irrigation systems Limited capacity among farmers for adopting new technologies	High	Agriculture	Adaptation
Improve food system integration, competitiveness, and resilience	**MEDIUM TERM** Set up a food security monitoring and early warning system to enable a prompt response to economic, climate, and other shocks Develop a functioning food safety system, aligned with international standards, to improve regional/international market access and domestic public health outcomes Continue expanding the capacity of the fast-growing domestic food processing industry, which is a significant contributor to job creation and (export) revenue Facilitate sustainable market linkages in the agrifood value chains, through programs that support farmer integration and modernization, widescale adoption of food quality and food safety standards, and value chain logistics through trade hubs, logistics platforms for perishable products, etc.	MoEc Private sector	Food security monitoring and early warning system in place (yes/no) Regulatory framework on food safety and quality strengthened and enforced Food processing production/export capacity and turnover increased Farm cooperatives and producer groups strengthened and expanded	Insufficient funding for infrastructure investment and modernization Limited public institutional capacity and private sector awareness Insufficiently developed regulatory and policy framework	High	Agriculture and food	Adaptation
Increase the resilience of infrastructure systems	**SHORT TERM** Develop an overarching, comprehensive, and proactive approach for identifying and managing critical infrastructure risks Identify the critical roads and bridges that are exposed to natural hazards Invest in strengthening 40 critical emergency response facilities and increase energy efficiency **MEDIUM TERM** Invest in strengthening the 60 schools and 13 hospitals exposed to severe flood risks and increase energy efficiency Strengthen the most critical road segments and bridges that are exposed to flood risk	MOTAI	Critical infrastructure at risk of climate hazards identified (yes/no) Emergency response facilities strengthened Kilometers of roads strengthened Schools and hospitals strengthened and more energy efficient	Limited funding for infrastructure investment and maintenance Limited institutional capacity	High	Disaster risk management Buildings Transport	Adaptation and mitigation
Develop land restoration programs	**SHORT TERM**	MoE MoF	National strategy developed (yes/no)	Limited capacity for developing portfolios	High	Agriculture Land	Adaptation

High-level objective	Priority policy actions	Lead agency, ministry, or stakeholder	Indicators for implementation	Key implementation barriers	Priority	Sector	Policy type
	Develop a landscape restoration approach as an element of a broader framework for the national adaptation plan Introduce rotational grazing or, if required, a grazing ban, when necessary, in the most degraded areas Repurpose harmful agricultural subsidies into incentives for landscape restoration initiatives and payments for ecosystem services Include forestry and landscape restoration as a green taxonomy activity **MEDIUM TERM** Create an enabling environment for innovations in landscape restorations through PPPs for climate research and development Develop a carbon credit framework for agriculture, forestry, and other land use projects, establish a robust system for monitoring and evaluating the success of restoration efforts Convene multidonor roundtables for large-scale resource mobilization for landscape restoration Create knowledge exchange and networking platforms on technology application successes in different contexts, with options for scaling up in similar contexts	MoEc Local governments	Hectares rehabilitated in land degradation hotspots	Limited funding for projects		Environment	

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Appendix: Leveraging trade and trade policy for the green transition

Over the past decade, Armenia has experienced significant growth in its export sector, primarily propelled by the commodity sector. Benefiting from a global commodities price boom, the export of copper ores as a share in total exports rose from 16 to 25 percent. Although service exports also grew, by an average of 8 percent annually, significantly contributing to the overall increase, the export of goods —dominated by commodities such as copper ores, hard liquor, ferroalloys, and gold—remained the primary driver (World Bank 2024c).

But the green transition, emerging climate mitigation policies, and stricter trading partner standards are reshaping export dynamics. As consumer preferences changing, demand patterns and global value chains are heightening their expectations, and demand for products with high emissions is declining. The EU Deforestation Regulation will require imports to prove they are deforestation-free, the German Supply Chain Due Diligence Act requires companies to respect environment throughout their supply chains, and the EU CBAM aims to prevent the relocation of GHG emissions from the EU to other countries. Analysis shows that, in Armenia, aluminum, a non-ferrous metal that only constituted 2 percent of total exports in 2020, would be most impacted in the first CBAM phase (World Bank forthcoming).

There could, however, be surprising upsides to the emerging climate mitigation policies, and opportunities can arise. For example, under the current EU CBAM proposal, nearly all of Armenia's ferrous metal exports to the EU (specifically ferro-alloys) are exempt, and most mineral and chemical products are not covered. This scenario may offer advantages, as unlike their EU counterparts, Armenian manufacturers could avoid CBAM-related costs on inputs, potentially increasing demand for upstream 'other mining' sectors not affected by the CBAM, making primary metals manufactured in Armenia more competitive on the EU market. Analysis also finds that that Armenia's exports are well below their potential, so there is substantial scope to enhance the country's participation in the emerging green economy by increasing the production and export of essential goods and services (World Bank 2024a).

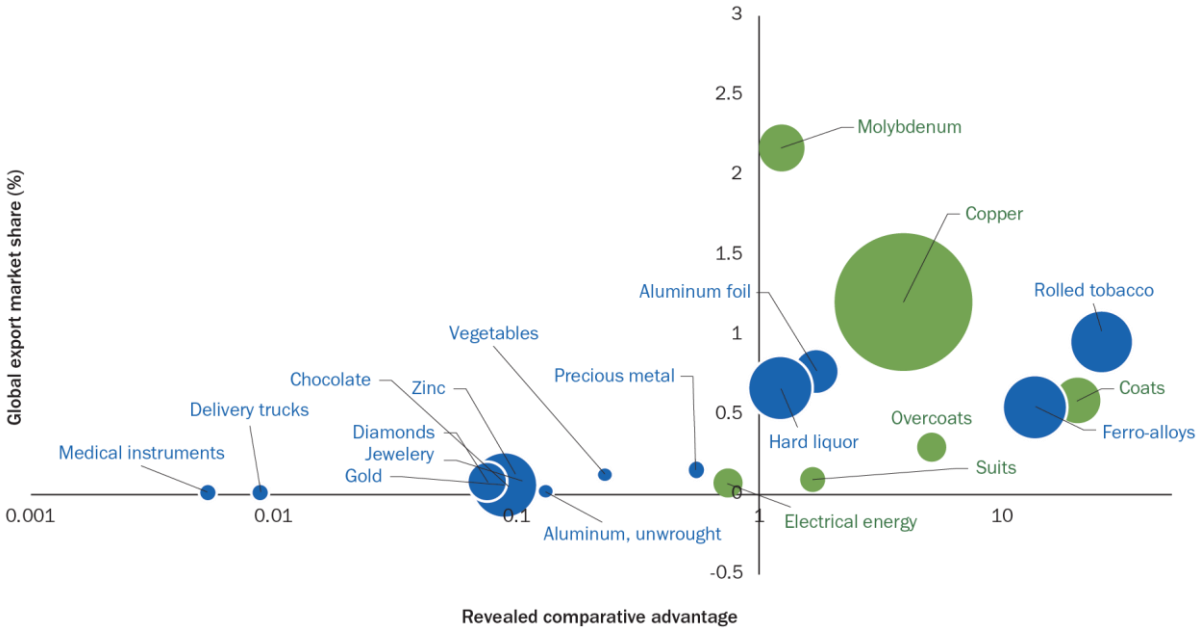
The manufacturing sector presents significant opportunity, particularly if it integrates green practices and technologies to reduce emissions intensities. Analysis reveals that, of Armenia's top five goods export sectors—other extraction, non-ferrous metals, manufacturers, iron and steel, and wearing apparel (figure A1)—the production and export of wearing apparel is relatively competitive, as its emissions intensity is lower than China and Vietnam (Chemutai and Jung, forthcoming). This can differentiate Armenian textiles in the global market, appealing to consumers and businesses seeking sustainable products,[61] presenting an opportunity to capitalize on global demand for low-emission products, as its competitive edge could open new markets and reduce the risk of noncompliance penalties, particularly in regions with high demand for eco-friendly goods. And with Armenia's energy mix projected to become more renewable, the textile industry could further reduce its footprint and drive innovation and jobs in the sector.

Climate critical minerals for low-carbon technologies are another sector of growing opportunity, where exports have grown 82-fold—from $0.02 to $1.4 billion—over the 2002–22 period (Snoussi-Mimouni and Avérous 2024). This has been dominated by copper (figure A1), a key element used in RE systems to generate power from solar, hydro, thermal, and wind energy. Armenia also exports other critical minerals—such as molybdenum, nickel, cobalt tungsten, niobium, tantalum, vanadium, and zirconium

[61] See World Bank (forthcoming, c).

ore—albeit at smaller volumes. These are critical components in the manufacturing of RE technologies, electronics, and electric vehicles. Aligning with global trends toward sustainable energy and low-carbon solutions, demand for these components is growing, and Armenia could increase its market share by leveraging existing mining operations and exploring new ones, while also focusing on sustainable and environmentally responsible mining practices to meet international standards (WTO 2024).

Figure A1: Armenia's current exports that could benefit from the green transition



Source: World Bank staff calculations, based on data from the Base pour l'Analyse du Commerce International (BACI) dataset.
Note: The green circles represent export sectors to leverage in the green transition.

Another opportunity is the export of environmental services, which could flourish on the backbone of the existing favorable environment for the services sector. Armenia's service sector employs 56 percent of the population and is seeing an uptrend in exports driven by information, communications, and technology sector. Service exports can circumvent the country's challenging topography and geopolitical issues, which restrict trade. As the country increasingly produces environmental goods, it will also need complementary environmental services, such as maintenance and repair services, which are key to keeping core environmental infrastructure in good condition. More specifically, it could scale up services along the solar value chain, as the domestic private sector is actively capitalizing on opportunities within the clean energy market, particularly in assembling solar modules and providing a variety of services throughout the solar photovoltaic project value chain.

Trade policy can play a critical role: since joining the Eurasian Economic Union in 2015 and facing increased tariff rates averaging 8.1 percent, Armenia's access to competitively priced industrial inputs and green technologies has been constrained, impacting its ability to compete globally. But it could leverage its existing bilateral trade agreements with Vietnam, China, Iran, and other countries to pursue climate-related trade goals more effectively. There is also substantial untapped export potential with major markets such as the United States, where exports—including of critical minerals and environmental services—could increase from $65 million to $416 million, and with Türkiye, where exports could increase to $124 million (World Bank 2024c). Strengthening trade relations with these countries, and enhancing ties with key regional partners such as Georgia, could significantly bolster Armenia's export growth.

But Armenia will need to address logistics and connectivity constraints that impede trade. Its landlocked geography, compounded by closed borders with Azerbaijan and Türkiye since the early 1990s, significantly hampers its trade integration and connectivity. Relying only on Georgia and Iran for land routes, Armenia encounters higher trade costs and logistical challenges, evidenced by its low rankings in the Logistics Performance Index (World Bank 2023a), which have been declining since 2014. This impacts timeliness, tracking, tracing, and the efficiency of international shipments, in which Armenia lags behind its regional peers.

To overcome barriers related to green standard compliance in export markets—particularly in mining, textiles, and food processing—Armenia could invest in adopting international standards and best practices. This includes building emissions measurement, reporting, and verification quality infrastructure, using tools such as e-Phyto for sanitary and phytosanitary controls, and expanding capacity-building programs for firms to meet international green certification demands. Such measures could significantly mitigate the potential impact of restrictive measures imposed by trading partners and enhance Armenia's export competitiveness in global value chains.