ECONOMICS OF CLIMATE CHANGE MITIGATION IN CENTRAL AND WEST ASIA

ASIAN DEVELOPMENT BANK

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Preface

With the signing of the Paris Agreement under the United Nations Framework Convention on Climate Change in 2016 came a global recognition that all countries must play their part in reducing greenhouse gas emissions if long term global temperature targets of 1.5°C or 2°C are to be achieved. It is the energy-rich countries who generally make the highest annual contribution per capita to these emissions due to the makeup of their economy. This report assesses the economics of mitigation greenhouse gas emissions in three such countries in Central and West Asia—Azerbaijan, Kazakhstan, and Uzbekistan—with a focus on the most emissions-intensive sectors, energy and transport.

This report is intended for policymakers, practitioners, and academics, to provide an overview of policy measures and technologies available for emission reduction, as well as scenarios of future emission trajectories in Azerbaijan, Kazakhstan, and Uzbekistan. A comforting result of the analysis, perhaps, is that a significant amount of emissions reduction (against the business-as-usual case) can be achieved with little to no cost, and with significant cobenefits to health. In addition, accompanying the report's output is a detailed custom-built model of the energy and transport sectors in each country, which has been distributed among stakeholders in each country for further development, analysis, and reporting on mitigation costs and options. It is hoped that this report, along with the model, will support the achievement of mitigation goals in these respective countries.

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Abbreviations

AC	alternating current
ADB	Asian Development Bank
AZN	Azerbaijan manat
CDM	Clean Development Mechanism
CFL	compact fluorescent light
CH_4	methane
CNG	compressed natural gas
CO_2	carbon dioxide
CO_2e	carbon dioxide equivalent
EU	European Union
GDP	gross domestic product
GHG	greenhouse gas
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit (German Society for International Cooperation)
HPP	hydropower plant
IEA	International Energy Agency
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
IRR	internal rate of return
JSC	Joint Stock Company
kWh	kilowatt hour
KZT	Kazakhstan tenge
LEAP	Long-Range Energy Alternatives Planning
LED	light-emitting diode
LNG	liquefied natural gas
MACC	marginal abatement cost curve
MENR	Ministry of Environment and Natural Resources (Azerbaijan)
MOE	Ministry of Energy
$MtCO_2e$	million tons of carbon dioxide equivalent
MW	megawatt
MWh	megawatt hour
NAMA	nationally appropriate mitigation action
NGV	natural gas vehicle
NPV	net present value
N_2O	nitrous oxide
OECD	Organisation for Economic Co-operation and Development
PM	particulate matter
PV	photovoltaic
RETA	regional technical assistance
SAARES	Azerbaijan State Agency for Alternative and Renewable Energy Sources

SHP	small hydropower plant
SOCAR	State Oil Company of the Azerbaijan Republic
TA	technical assistance
tCO_2e	ton of carbon dioxide equivalent
TPES	total primary energy supply
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
UZS	Uzbekistan som

Executive Summary

Introduction

The ecological complexity of the Central and West Asian region gives way to diverse ecosystems with rich natural resources and hydrocarbon reserves; countries in this region are not only exposed to climate change risks, but there is growing recognition that their carbon-intensive economies necessitate greenhouse gas (GHG) mitigation.

This report provides a detailed assessment of the costs, benefits, and investment opportunities for GHG abatement in the energy and transport sectors of Azerbaijan, Kazakhstan, and Uzbekistan, and provides an understanding of the indirect benefits to human health and energy security.

Regional Context

The climate change impacts already experienced in Central and West Asia are varied, multifaceted, and likely to continue to put pressure on ecosystems in this region. The presence of glaciers and snow-packed mountains, on which countries in this region are highly dependent for water supply, means the region is facing cycles of boom-and-bust for water, especially for hydropower and agriculture. Ecosystems in the region are threatened by climate change; mountains and grasslands are under stress from climate-induced variability in precipitation, as well as from increased temperatures leading to expanding desertification. Transportation systems in this region are at risk of flooding and landslides from extreme precipitation events, permafrost melt, and glacial lake outbursts.

Growing populations and abundant natural resources in Azerbaijan, Kazakhstan, and Uzbekistan have helped them liberalize their economies and stimulate development since gaining independence from the former Soviet Union in the early 1990s, seeing large and exponential growths in gross domestic product (GDP) in the past decade.

The rich hydrocarbon reserves in each of these countries have been a key contributor to this growth, both as a source of export revenue and for meeting domestic energy requirements. However, this reliance on fossil fuels, coupled with the legacy of carbon-intensive Soviet infrastructure and capital equipment in Azerbaijan, Kazakhstan, and Uzbekistan, have given rise to economies with high GHG emissions per unit of GDP. The results of the national economic models developed for each of the three countries under this report suggest that increasing demand for carbon-intensive energy, driven by population and income growth, will lead to a continued rise in GHG emissions through 2050.

Energy production and use in these countries have been dominated by fossil fuels, which make up 99% of the combined total primary energy supply, consisting primarily of coal as the single largest primary energy source in Kazakhstan, and of natural gas, which dominates in Azerbaijan and Uzbekistan. This is also reflected in the structure of electricity generation in the region, which consists primarily of fossil fuel energy sources, with hydropower making up no more than 12% of the fuel composition. The endowment of energy resources favors fossil fuels in all three countries; Kazakhstan has abundant coal resources, Azerbaijan has significant oil and natural gas resources, and Uzbekistan has large natural gas resources and coal reserves. Given these large reserves, all three countries are expected to continue to rely heavily on fossil fuels in the next few decades.

Reliance on the heavy fossil-fuel-based energy mix has resulted in the economies of Azerbaijan, Kazakhstan, and Uzbekistan being carbon-intensive. In all three countries, more than 75% of the total 2010 GHG emissions were a result of activities in the energy and transport sectors, distantly followed by the agriculture sector, accounting for no more than 12% of country emissions in each country. Even though the three countries account for a small fraction of global GHG emissions—about 1% of global carbon dioxide (CO_2) emissions in 2013 (European Commission JRC Joint Research Centre, 2015)—when compared to countries with similar per capita income, all three show relatively high GHG intensity of GDP.

However, there is growing recognition of the need and opportunity to re-examine resource options and growth strategies that aim for low-carbon growth. Cost-effective clean energy technologies and the promotion of energy efficiency, fuel switching, and low-carbon transport can play a crucial role in achieving increased development with low climate impacts.

Each of the three countries has developed its own policies and targets in response to climate change. Azerbaijan's efforts have thus far focused on identified renewable power targets, introduction of Euro-4 vehicle standards, and development of the State Program of Poverty Reduction. Kazakhstan, on the other hand, has developed an emissions trading system, natural gas and alternative power targets, introduction of Euro-5 vehicle standards, and an overall green growth strategy. Uzbekistan's climate change efforts have focused on developing residential building efficiency standards, a solar road map, and a state program on hydropower development. Azerbaijan and Kazakhstan have announced intended greenhouse reduction targets for 2030.

Cost and Benefits of Greenhouse Gas Mitigation

Three national-level transport-energy-economic models were developed to assess the costs and benefits of GHG mitigation, using the Long-Range Energy Alternatives Planning (LEAP) system. LEAP is a well-known and widely used platform for building integrated models of energy and transport systems for GHG mitigation policy analysis, and was selected for this study because of its flexibility, transparency, and user friendliness. The national LEAP models simulate the energy and transport systems for the corresponding country, including all sources of energy demand and supply that cause GHG emissions.

LEAP models were run to project baseline (No Action) emissions levels to 2050 and analyze the direct costs and the human health and energy security benefits of a selected set of mitigation measures. Marginal GHG abatement cost curves were subsequently developed as a means to illustrate and compare the costs and potential of these GHG abatement options in the energy and transport sectors of each country.

Abatement measures were selected on the basis of their feasibility and appropriateness for each country's energy and transport sectors, following extensive stakeholder consultation and review of prevailing (and anticipated) government goals, policies, and targets. Several categories of mitigation actions were explored, either price-related mechanisms (such as carbon pricing or changes to fuel prices) or technical options (such as technology deployment, differential resource management practices, or the attainment of a non-price target). Combinations of multiple technical mitigation options were also explored, to determine whether any synergistic effects would be realized by implementing a portfolio of mitigation options at once, rather than individually.

The LEAP analysis indicates that in each country, there is a selection of technical mitigation measures with high mitigation potential that can be accessed at either a direct cost savings or a very low marginal cost per ton of abatement. Efficiency improvements in buildings and vehicles fall into this category across the three countries, and in some cases renewable energy options are also cost-effective (e.g., small hydropower). Many of the highest-cost measures contribute relatively little to further GHG abatement, although high-cost options may still be worth considering if they advance other social goals, such as economic development.

For Azerbaijan, the transition into residential and commercial compact fluorescent lighting, improved building insulation, small hydropower, low carbon energy integration into agriculture, and renewable energy targets were found to be both particularly cost-effective and in keeping with the country's long-term development goals. The analysis of cobenefits associated with the mitigation options produced only modest impacts on human health in terms of avoided mortalities resulting from improved air quality. However, some options that produce the largest human health benefits also produce the overall largest improvements in energy security.

Kazakhstan would realize considerable GHG abatement at a low cost by making improvements to its vehicle fleet, either by fuel switching from gasoline or diesel into compressed natural gas in a larger number and more types of vehicles. Other ways to realize emissions reductions with cost savings include improvement in heat insulation in existing buildings, deployment of light-emitting diode (LED) outdoor lighting in municipalities across the country, as well as constructing new homes with more stringent heating efficiency standards. Rehabilitation of the National Grid, thereby reducing electricity losses, offers significant GHG reductions because the power system is primarily coal-based. However, once electricity generation has shifted to renewables, natural gas, and nuclear, the emissions-reducing impact of grid improvements is diminished. A few of the mitigation options examined for Kazakhstan have significant cobenefits, including large human health benefits (avoided mortalities in the thousands).

Residential building efficiency improvements in Uzbekistan produce significant energy and emissions savings. Furthermore, the State Program on Development of Hydropower is also indicated to be a cost-effective approach to GHG mitigation; in particular, large hydropower installations detailed in the midterm development plan have the greatest potential, and it can be accessed at a lower direct cost than with small or distributed hydro stations. Similarly, the Residential Renewable Energy Scenario shows the effects of meeting 5% of residential energy demand with distributed renewables by 2050, although this percentage can conceivably be increased. District heating also offers substantial mitigation potential. The combination of all the mitigation measures analyzed for Uzbekistan result in measurable fuel savings, human health benefits, and improvements in energy security, particularly with respect to the share of renewable energy in total energy supply.

Nationally Appropriate Mitigation Actions and Investment Concept Notes

Through stakeholder consultation in each country, and supported by the results of the LEAP model, one potential nationally appropriate mitigation action (NAMA) was identified and elaborated for each country. NAMAs emerged as part of the negotiations under the United Nations Framework Convention for Climate Change (UNFCCC) for a long-term climate change agreement. Work on NAMAs is still in the early stages in Azerbaijan, Kazakhstan, and Uzbekistan, and the formal institutional framework supporting NAMA development and implementation has yet to be established.

For Azerbaijan, a NAMA promoting agro-energy development based on renewable energy was identified and elaborated. The NAMA supports construction of renewable energy facilities at agricultural complexes in Azerbaijan, revises the normative and regulatory framework for renewable energy, and pilots the concept at the Samukh agro-energy complex. For Kazakhstan, the proposed NAMA fosters the use of natural gas in the transport sector—expanding the refueling infrastructure for compressed natural gas, vehicle conversion, and technical capacity support—as well as developing a national energy efficiency support system, which would create an online system for tracking, reporting, and evaluating progress on energy efficiency improvements. For Uzbekistan, the proposed NAMA accelerates the deployment of small-scale hydropower, and aims to address institutional and investment barriers to the acceleration of small-scale hydropower and finance the rehabilitation of existing plants and construction of new small hydropower plants.

The study identified a climate change investment concept for each of the three NAMAs. These are the solar photovoltaic and biogas plants at the Samukh Agro-Energy Residential Complex in Azerbaijan, construction of a network of 10 compressed natural gas refueling stations in Kazakhstan, and construction of the Tuyabuguzskaya small hydropower plant in Uzbekistan. To effectively attract international climate finance there is a need for developing the requisite domestic financial institutions that can attract climate funds to Azerbaijan, Kazakhstan, and Uzbekistan. The respective governments will likely need to engage national financial institutions to help with accessing international climate funds by leveraging domestic resources for clean energy and transport measures.

Introduction

Background

The ecological complexity of the Central and West Asian region gives way to diverse ecosystems with rich natural resources and hydrocarbon reserves; countries in this region are not only exposed to climate change risks, but there is growing recognition that their carbon-intensive economies necessitate reduction in greenhouse gas (GHG) emissions in line with global efforts to mitigate climate change.

This report is a product of the Economics of Climate Change in Central and West Asia, a regional technical assistance (TA) project of the Asian Development Bank (ADB). The TA project was designed to identify costs and opportunities in investments for low-carbon growth and climate resilience and low-carbon growth, under two components:

(i) **mitigation of climate change**, which assessed the costs and benefits of GHG emission reduction measures and formulated low-carbon growth investment proposals for energy and transport in the most carbon-intensive countries in the region, i.e., Azerbaijan, Kazakhstan, and Uzbekistan; and

(ii) **adaptation to climate change**, which assessed the costs and benefits of implementing adaptation measures to reduce the adverse effects of climate change on energy and water resources in the most vulnerable countries, i.e., Afghanistan, the Kyrgyz Republic, and Tajikistan.

This report describes the process and outcomes of the mitigation component of the TA project, and seeks to fill the gap in knowledge of opportunities, costs, and benefits of GHG abatement in the region, and support the planning of medium- to long-term mitigation policy. This is achieved through the following analysis:

- **National level transport-energy economic modeling.** An assessment of the costs and benefits of GHG mitigation in each of the three countries, using the Long-Range Energy Alternatives Planning (LEAP) system.
- **Indirect cobenefits of GHG abatement options.** An analysis of indirect cobenefits achievable from GHG mitigation and included reduced air pollutant emissions, human health benefits of reduced air pollution, and improved energy security.
- **Nationally appropriate mitigation actions (NAMAs).** Identification of NAMAs through stakeholder consultation in each country, and supported by the results of the LEAP model.
- **Climate change investment options.** Development project concept notes in support of the NAMAs.

Climate Impacts

While largely arid and semiarid, the Central and West Asian region is composed of a diverse mix of ecosystems, from grasslands and rangelands, to glaciers and mountains, and deserts and river basins. This complexity of ecologies is at serious risk from climate change impacts, which threaten the region's resource-dependent economies, especially in water-sensitive areas.[1]

Climate change presents unprecedented threats to the achievement of development goals in the countries of Central and West Asia. Preliminary evidence indicates that Central and West Asia countries are hit hard by climate change. Predicted warmer temperatures, accelerated glacial melt, reduced winter snow cover and associated changes in river flows, and more frequent and intense drought and floods threaten the stability of water supply for agriculture, hydropower, and human consumption—one of the major concerns in the arid and semiarid regions of Central and West Asia.[2] More frequent droughts, catastrophic flooding from glacial lake outbursts, and landslides caused by destabilization of mountain slopes will lead to a progressive increase in economic losses and risk to the population, and reduce the ability of communities to move out of poverty. These adverse effects, which will be compounded by projected population growth in the 21st century, will exacerbate underlying national socioeconomic and environmental constraints such as crumbling infrastructure, land degradation, and limited institutional capacity. Key river basins, such as the Amu Darya and Syr Darya, are important to the economies of several countries in the region, as they supply water to vast expanses of agricultural land and hydropower plants for electricity generation.

Climate change impacts already experienced in Central and West Asia, and which will likely continue to put pressure on ecosystems in this region, are varied and multifaceted.

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[1] ADB. 2010. *Climate Change in Central and West Asia: Routes to a More Secure, Low-Carbon Future.* Manila.

[2] IFAD. 2009. *Climate Change Impacts – Central Asia.* https://www.ifad.org/documents/10180/957d7d1c-4487-4c3f-ae59-f167fdb4d571

The presence of glaciers and snow-packed mountains, on which countries in this region are highly dependent for water supply, means the region is facing cycles of boom-and-bust for water, especially for hydropower and agriculture. The recession and melting of glacial ice will increase water supply, but also flooding, in the short term; however, it will result in increased droughts and much-reduced river flows in the long term. For instance, Uzbekistan draws its water supply primarily from the Amu Darya river, which flows from the Tien Shan mountain range, whose glaciers have lost nearly a third of their mass; this loss will have a ripple effect on agriculture in the country, whose economy is largely dependent on irrigated agriculture.[3] Azerbaijan currently faces land degradation and erosion due to agricultural overuse and land conversion; these problems are expected to be exacerbated by climate change-induced desertification.[4]

Transportation systems in this region are at risk of flooding and landslides from extreme precipitation events, permafrost melt, and glacial lake outbursts. The transport system in Kazakhstan, which includes roads and railways as well as river transport, is climate-sensitive and exposed to varying impacts from climate change; reliability and efficiency of regional and transboundary trade can be adversely affected by fluctuations in temperature, incidence of flooding, and intense storms.[5]

Regional Overview

Growing populations and abundant natural resources in Azerbaijan, Kazakhstan, and Uzbekistan have helped them stimulate development since gaining independence from the former Soviet Union in the early 1990s, seeing large and exponential growths in gross domestic product (GDP) in the past decade.[6]

The rich hydrocarbon reserves in each of these countries have been a key contributor to this growth, both as a source of export revenue and for meeting domestic energy requirements. However, this reliance on fossil fuels, coupled with the legacy of carbon-intensive Soviet infrastructure and capital equipment in Azerbaijan, Kazakhstan, and Uzbekistan, have given rise to economies that have high levels of GHGs per unit of production, as compared to other countries with comparable levels of development (Figure 7).

Energy production and use in these countries are dominated by fossil fuels, which make up 99% of the combined total primary energy supply, consisting primarily of coal as the single largest energy source in Kazakhstan, and of natural gas, which dominates in Azerbaijan and Uzbekistan. This is also reflected in the structure of electricity generation in the region, which consists primarily of fossil fuel energy sources, with hydropower making up no more than 12% of the fuel composition. The endowment of energy resources favors fossil fuels in all three countries; Kazakhstan has abundant coal resources, Azerbaijan has significant oil and natural gas resources, and Uzbekistan

[3] U. Luterbacher et al. 2008. Glaciers and efficient water use in Central Asia. In B. Orlove, E. Wiegandt, and B. H. Luckman, eds. *Darkening Peaks: Glacier Retreat, Science, and Society*. Los Angeles, CA: University of California Press.

[4] M. Westphal et al. 2011. *Regional Climate Change Impacts Study for the South Caucasus Region.* Tbilisi, Georgia: United Nations Development Programme. http://eiec.gov.ge/getattachment/თემები/კლიმატის-ცვლილება/Documents/Publication/GE_SC-Regional-Climate-Change-Impacts-Study-for-the-South-Caucasus-Region-CC-2011.pdf.aspx

[5] J. Shah et al. 2013. *Kazakhstan: Overview of climate change activities*. Washington DC: World Bank Group. http://documents.worldbank.org/curated/en/859941468040174046/Kazakhstan-Overview-of-climate-change-activities

[6] Asian Development Bank (ADB). 2015a. *Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: Final Summary Report and Investment Concept Notes.* Consultant's report. Manila (TA 8119-REG).

has large natural gas resources and modest coal and coal reserves. All three countries have posted strong economic growth over the last decade. From 2000 to 2010, real GDP grew 95% in Uzbekistan, 220% in Kazakhstan, and 400% in Azerbaijan. Per capita real GDP in purchasing power parity (at constant 2011 international $) improved as well, particularly in Kazakhstan and Azerbaijan. Industry and services together account for over 80% of GDP in the three countries, with services playing the biggest role in Kazakhstan and Uzbekistan and industry in Azerbaijan. The contribution of agriculture generally declined across the region, with Uzbekistan remaining the most dependent on this sector. In the absence of climate policy intervention, increasing demand for carbon-intensive energy, driven by population and income growth, is expected to lead to a continued rise in GHG emissions in the coming decades.

However, there is an increasing awareness for the need to slow the rise of GHG emissions and switch to lower-carbon sources of energy. Azerbaijan, Kazakhstan, and Uzbekistan offer mitigation opportunities involving improved clean energy (i.e., energy efficiency and renewable energy), fuel switching, more efficient industrial processes, improved waste management systems, and land restoration.[7]

In 2015, Azerbaijan and Kazakhstan prepared and submitted Intended Nationally Determined Contribution (INDC) reports to the United Nations Framework Convention on Climate Change in support of the Conference of the Parties in December 2015. In its INDC, Azerbaijan committed to a reduction of 35% of total emissions compared to the 1990 base year, equivalent to approximately 25,000 gigajoules of carbon dioxide equivalents (CO_2e) by 2030. Azerbaijan intends to achieve this across various sectors through a combination of implementing legislative regulations, upgrading technologies in use, rehabilitating old infrastructure, and encouraging efficiency in resource use (e.g., energy and fuel). Kazakhstan also committed to GHG reductions in its 2015 INDC; its unconditional 15% reduction target is anticipated to be achievable through adoption of its recently enacted laws on energy saving, energy efficiency, and renewable energy, as well as the implementation of the Green Economy Concept, which includes modernization of key infrastructure, development of sustainable transport, and enhancement of forest covers as some of its main mitigation measures.

[7] ADB. 2015b. *Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: The Economics of Reducing Greenhouse Gas Emissions in the Energy and Transport Sectors.* Consultant's report. Manila (TA 8119-REG).

Methodology

The analysis and results of the report are underpinned by results of transport-energy-economic models for Azerbaijan, Kazakhstan, and Uzbekistan developed and run for the Asian Development Bank regional technical assistance (TA) for Economics of Climate Change in Central and West Asia, using the Long-Range Energy Alternatives Planning (LEAP) system. LEAP is a well-known and widely used platform for building integrated models of energy and transport systems for greenhouse gas (GHG) mitigation policy analysis, and was selected for this study because of its flexibility, transparency, and user friendliness (Box 1).[8] The national LEAP models simulate the energy and transport systems for the corresponding country, including all sources of energy demand and supply that cause GHG emissions.

The analysis of the three countries' energy and transport systems was carried out in two stages, the overall scope of which is shown in Table 1. More detailed information on the LEAP model, including detailed listing of sectors, is found in the Appendices of ADB (2015b).

In the first stage, the LEAP models were used to: (i) project baseline emissions levels under the No Action Scenario to 2050, and (ii) assess counterfactual GHG mitigation scenarios to understand the direct costs and cobenefits of selected GHG abatement options in the transport and energy sectors.

For the mitigation scenarios, several categories of abatement options were explored, either price-related mechanisms (such as carbon pricing or changes to fuel prices) or technical options (such as technology deployment, differential resource management practices, or the attainment of a non-price target). Combinations of multiple technical mitigation options were also explored,

[8] The LEAP platform and model code for the three countries is freely available on the Stockholm Environment Institute Community for Energy, Environment, and Development website: http://www.energycommunity.org/

Box 1: Long-Range Energy Alternatives Planning Model of the Stockholm Environment Institute

Modeling tools

The Long-Range Energy Alternatives Planning (LEAP) system, is a modeling tool developed by the Stockholm Environment Institute (SEI) (Stockholm Environment Institute 2015b). LEAP is a platform for building integrated models of energy and transport systems and greenhouse gas emissions and is widely used for mitigation policy analysis.

LEAP was selected for this study because the methodological options inherent in the platform allow useful models to be constructed even when data are scarce—as is sometimes the case in Azerbaijan, Kazakhstan, and Uzbekistan. Top-down approaches can be taken for sectors with limited data, while more detailed analyses of technologies and energy end uses can be conducted for sectors with more available information. The energy, transport, and non-energy projections in the national models are influenced by a few significant cross-cutting variables: population, gross domestic product, and value added. All three are exogenous inputs to the models.

Model scope and boundaries

Three national-scale LEAP models were constructed for this study—one for each participating country; the modeling was therefore done at different levels of detail and had varying sectoral emphases.

Energy demand is categorized by economic sector, subsector, fuel, and (where possible) end use. On the supply side, all energy producing industries—from primary resource extraction through conversion and delivery to end customers—are represented. Physical constraints on primary (naturally occurring) energy sources are also represented, such as reserves of fossil fuels and annual yields of renewable resources.

The models incorporate an accounting of direct costs and benefits of the energy and transport systems and mitigation measures, developed from the perspective of society as a whole without explicit consideration of distributional impacts (i.e., who pays or benefits). Four primary types are represented:

(i) Capital (equipment) costs
(ii) Operations and maintenance costs
(iii) Fuel costs
(iv) Other implementation costs for mitigation measures (e.g., governmental program administration costs)

Reductions in any of these costs as a result of mitigation are considered a benefit (e.g., decreased fuel costs due to an efficiency measure). All direct costs and benefits are expressed in real (constant monetary year) terms in the models. When discounted costs are reported, a 7% real discount rate is used.

In several cases, policies and targets that governments have recently introduced to reduce GHG emissions are excluded from the No Action Scenario. Instead, these are analyzed as mitigation options to properly determine their abatement potential and cost-effectiveness.

to determine whether any synergistic effects would be realized by implementing a portfolio of mitigation options at once, rather than individually. Actions were chosen for analysis in the LEAP model on the basis of their feasibility and appropriateness for each country's energy and transport sectors, following extensive stakeholder consultation and review of prevailing (and anticipated) government goals, policies, and targets. Marginal GHG abatement cost curves were subsequently developed as a means to illustrate and compare the costs and potential of the abatement options.

Table 1: Scope of Analysis

Subsectors	• Electricity generation (e.g., hydropower, transmission, and distribution) • Heat generation (e.g., commercial, residential heating) • Transport (e.g., road, aviation, rail)
Time period	• 1995, 2000–2050
Abatement options	• Price-based mitigation options • Technology-based mitigation options
Outputs	• GHG emissions levels (CO_2, CH_4, N_2O) • Energy use and power generation mix • Abatement level and cost of mitigation options • Air pollution reduction • Human health (i.e., reduced mortality) • Energy security benefits

CH_4 = methane, CO_2 = carbon dioxide, GHG = greenhouse gas, N_2O = nitrous oxide.
Source: ADB. 2015b. *Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: The Economics of Reducing Greenhouse Gas Emissions in the Energy and Transport Sectors*. Consultant's report. Manila (TA 8119-REG).

The second stage, related to analyzing the cobenefits of mitigation, was prepared as follows:

(i) The reduction in air pollutants was estimated using LEAP outputs;
(ii) The assessment of human health benefits of mitigation was developed in a separate spreadsheet model using quantitative outputs from LEAP; and
(iii) The energy security benefits were estimated based on quantitative outputs from LEAP.

Scenario Approach

The No Action Scenario comprises both historical data and a projection to 2050 and serves as the baseline for the mitigation analysis. Designed in collaboration with national stakeholders, it envisions a future in which no significant new mitigation policies are enacted and historical trends in key drivers of energy use and emissions continue.

The mitigation scenarios share the key growth variables (see below) of the No Action Scenario. These options were subdivided into **pricing mitigation miniscenarios**, which add one discrete price-based mitigation option to the No Action Scenario, such as a change in fuel or carbon prices; **technical mitigation miniscenarios**, which add one discrete physical or behavioral mitigation option to the No Action Scenario, such as a change in technology deployment, differential resource management practices, or the attainment of a non-price target; and **combined mitigation scenarios**, which combine multiple technical miniscenarios into a portfolio of mitigation options.

The miniscenarios were defined and their input data were collected through reviews of national literature and consultations with national stakeholders. Miniscenarios were not created for potential mitigation options for which no nationally appropriate modeling inputs could be determined. This approach was intentional and designed to produce an analysis that is as reflective of national circumstances, feasibility, and plans as possible.

Assumptions of Population, Gross Domestic Product, and Value Added

Three significant cross-cutting variables were used in the scenarios: population, gross domestic product, and value added, which are exogenous inputs. Projections of these basic variables are used in subsequent economic analysis for this study; they also define the basis for projecting expected economic growth, and therefore GHG emissions, in the No Action Scenario (Table 2).

Table 2: Projections of Population, Gross Domestic Product, and Value Added per Country

Country	Variable	Projection Technique
Azerbaijan	Population	Growth at average annual 1.14% rate observed in historical data from 2000 to 2010.
	GDP	Short-term projections of 4.3% per year (2013–2019) from International Monetary Fund (2014); after 2019, growth at average annual 3.6% rate observed for 2010–2019.
	Value added	Calculated as GDP multiplied by shares for sectoral value added; shares grow at average annual % rates observed in historical data.[a] Shares are normalized so sum of shares = 100%.
Kazakhstan	Population	Projected population growth at average annual 1.13% through 2050 from Ministry of National Economy of the Republic of Kazakhstan Committee on Statistics (2014).
	GDP	Short-term projections of real growth of 1.5% in 2015, 2.3% in 2016, and 3.4% in 2017 reported in news@mail.ru (2015); after 2017, 4% annual growth assumed per President of the Republic of Kazakhstan (2014).
	Value added	Growth at same % rate as GDP.
Uzbekistan	Population	Projected population growth of 0.64% per year up to 2050 from United Nations Department of Economic and Social Affairs (2012).
	GDP	Projection of annual average growth of 8.2% from 2014–2030 declining to 5% by 2050 provided by the Ministry of Economy of the Republic of Uzbekistan and consistent with the United Nations Development Programme 2015 analysis of targets for the energy sector (2015).
	Value added	Calculated as GDP multiplied by shares for sectoral value added; shares grow at average annual % rates observed in historical data.[a] Shares normalized so sum of shares = 100%. Exception: short-term projections for industrial value added (through 2019) from President of the Republic of Uzbekistan (2015).

GDP = gross domestic product.

[a] Changes limited to a few percent per year to avoid unreasonable developments over the long term.

Source: ADB. 2015b. *Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: The Economics of Reducing Greenhouse Gas Emissions in the Energy and Transport Sectors*. Consultant's report. Manila (TA 8119-REG).

Indirect Cobenefits

The analysis of the indirect cobenefits of mitigation focuses on air pollution, human health, and energy security benefits, as these are the metrics for which data are readily available to quantify impacts. All cobenefits analyzed as part of the study were expressed in comparison to the No Action Scenario.

The human health assessment focused on the benefits of reduced air pollutant concentrations from mitigation options that reduce emissions from electricity generation and transport. Electricity and transport are the two subsectors for which sufficient data and methods were available for establishing a quantifiable relationship between air pollutants and health cobenefits, such as reduced mortality.

The human health benefits analysis was based on emissions of fine particulate matter ($PM_{2.5}$), since this pollutant has dominated cost–benefit analyses of reduced air pollution in the United States and elsewhere. As documented in the *Interim Report*[9] for this TA project, inhaling $PM_{2.5}$ can lead to adverse health outcomes in humans, including premature mortality.[10] The study estimated the avoided mortalities from reducing primary $PM_{2.5}$, and the associated sulfur dioxide and nitrogen oxides, and then monetized the value of these avoided mortalities.

The study also quantified the energy security benefits of the proposed mitigation actions. Increased energy security means that a country is more resilient and better able to withstand shocks and minimize disruptions in economic functioning, human health and environmental quality. Improvements to energy security can include changes based on fuel diversity, transport diversity, import diversity, price volatility, energy efficiency, and infrastructure reliability. Furthermore, an increase in domestically produced fuels with low fossil fuel content, such as renewable energy, reduces security risks and is more environmentally benign, thus contributing to cobenefits.

The metrics associated with these two main categories of cobenefits analyzed in this study are presented in Figure 1.

Figure 1: Cobenefit Metrics

Human Health Cobenefits	Energy Security Cobenefits
Cumulative avoided mortalities	Fuel savings
Monetized value of avoided	Energy intensity
	Carbon intensity
	Renewable energy percentage

Source: ADB. 2015b. *Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: The Economics of Reducing Greenhouse Gas Emissions in the Energy and Transport Sectors*. Consultant's report. Manila (TA 8119-REG).

9 ADB. 2014b. *Economics of Climate Change in Central and West Asia - Mitigation Component: Interim Report.* Consultant's report. Manila (TA 8119-REG).

10 ADB. 2015a. *Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: Final Summary Report and Investment Concept Notes.* Consultant's report. Manila (TA 8119-REG).

Baseline No Action Scenario

The foundational scenario in this report is the No Action Scenario. The No Action Scenario for each country is calibrated with the most recent available detailed historical data (Table 3), and is run to 2050.

Table 3: Model Years

Country	Historical Period	Projections
Azerbaijan	2000–2010	2011–2050
Kazakhstan	2000–2012	2013–2050
Uzbekistan	1995–2011	2012–2050

Source: ADB. 2015b. *Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: The Economics of Reducing Greenhouse Gas Emissions in the Energy and Transport Sectors*. Consultant's report. Manila (TA 8119-REG).

In several cases, governments recently introduced policies and targets to reduce greenhouse gas (GHG) emissions. These have been purposely excluded in the No Action Scenario (Table 4), and are instead analyzed as abatement options under the mitigations scenarios to assess their abatement potential and cost-effectiveness.

Table 4: Existing Policies and Targets Not Reflected in the No Action Scenario

Azerbaijan	Kazakhstan	Uzbekistan
• Renewable power target • State Program of Poverty Reduction • Introduction of Euro-4 vehicle standards	• Early vehicle retirement • Emissions Trading System • Alternative power target • Natural gas power target • Green growth strategy • Introduction of Euro-5 vehicle standards	• Residential building efficiency standards • State program on development of hydropower • Solar road map

Source: ADB. 2015b. *Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: The Economics of Reducing Greenhouse Gas Emissions in the Energy and Transport Sectors*. Consultant's report. Manila (TA 8119-REG).

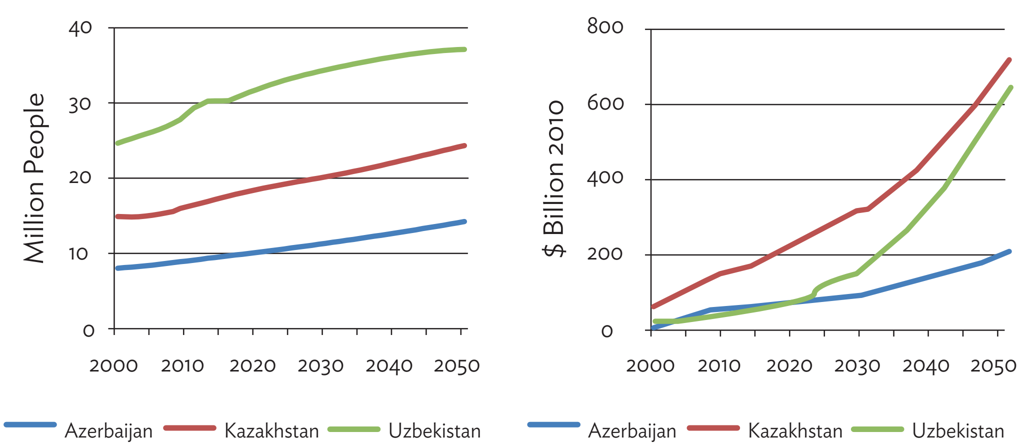
Energy Production and Use

The economies of Azerbaijan, Kazakhstan, and Uzbekistan are carbon-intensive when compared to countries with similar per capita incomes. A variety of reasons underlie this phenomenon. A legacy of energy-intensive Soviet infrastructure, abundant domestic supplies of fossil fuels, and climatic conditions (particularly the cold climate in Kazakhstan) all play a role in driving energy use and emissions. Fossil fuel production for export and domestic use contributes significant and predominant GHG emissions in all three countries, while energy-intensive industries are also an important emitter in Kazakhstan and Uzbekistan. The power sectors in the three countries are currently dominated by fossil technologies.

The outlook for energy production and use in these countries indicates growing population and economic activity, both of which increase demands for energy and other resources. From 2000 to 2010, while real gross domestic product (GDP) grew significantly, populations grew at least 9% in the three countries across the same period. Based on this trajectory, the No Action Scenario for population and GDP in the three countries are envisioned to continue to rise (Figure 2).

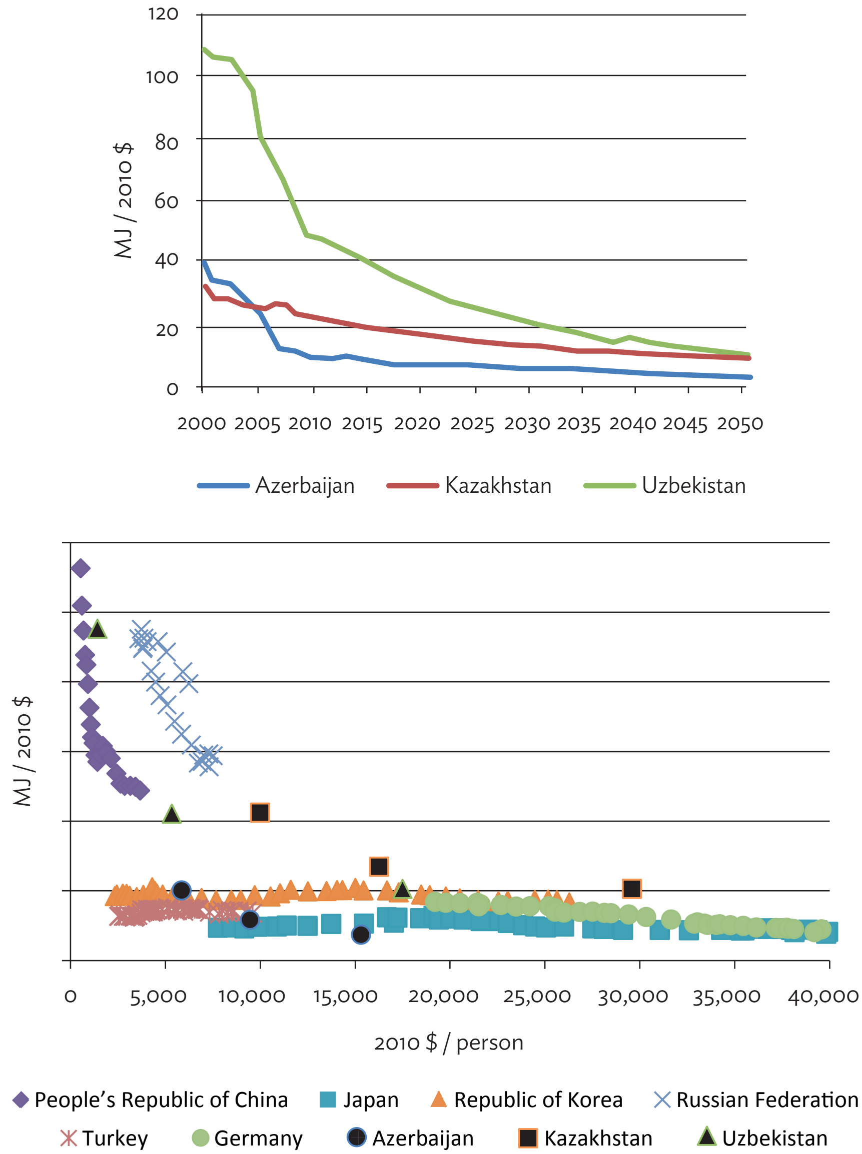
Figure 3A shows the energy intensity of GDP as improving under the No Action Scenario, primarily from energy efficiency improvements realized from different measures in Azerbaijan, Kazakhstan, and Uzbekistan. Figure 3B compares these energy intensity projections with those of six other countries (People's Republic of China, Germany, Japan, the Republic of Korea, the Russian Federation, and Turkey), by plotting economy-wide energy intensities of GDP versus per capita income from three time periods (baseline, and 2030 and 2050 projections) of the three countries under study against data from a selection of reference countries.

Figure 2: Population (left) **and Gross Domestic Product** (right) **in Azerbaijan, Kazakhstan, and Uzbekistan (No Action Scenario through 2050)**



Source: ADB. 2015b. *Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: The Economics of Reducing Greenhouse Gas Emissions in the Energy and Transport Sectors*. Consultant's report. Manila (TA 8119-REG).

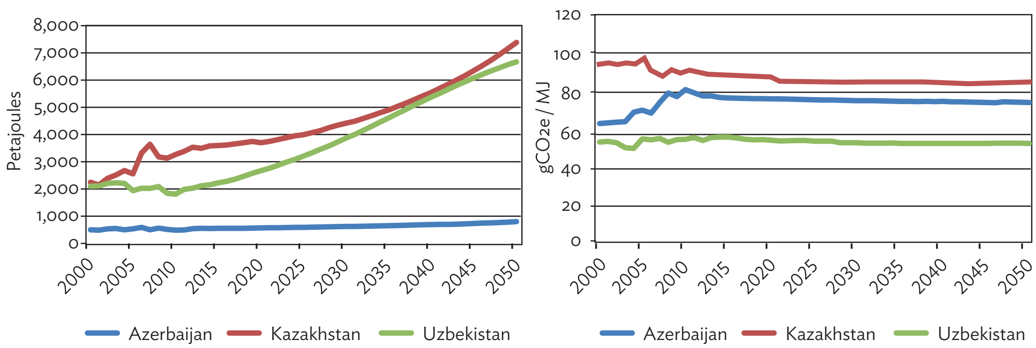
Figure 3: Energy Intensity of Gross Domestic Product (left) **and Energy Intensity** (right) **vs. Per Capita Income (No Action Scenario through 2050)**



Sources: International Energy Agency. 2014. *World Energy Outlook*. http://www.oecd-ilibrary.org/energy/world-energy-outlook-2014_weo-2014-en; World Bank. World Development Indicators. Accessed March 2016 at http://data.worldbank.org/data-catalog/world-development-indicators; ADB. 2015b. *Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: The Economics of Reducing Greenhouse Gas Emissions in the Energy and Transport Sectors*. Consultant's report. Manila (TA 8119-REG).

As the above figures illustrate, the projected decreasing energy intensities in Azerbaijan, Kazakhstan, and Uzbekistan are consistent with historical evidence from the reference countries. Both the trend with rising incomes and the magnitude of the projected intensities generally agree with other countries' experiences. The most significant difference is that the economy-wide intensity in Kazakhstan is somewhat higher than in other countries at comparable income levels. This result is likely due to the structure of the industrial and power sectors in Kazakhstan as well as climatic influences.

Figure 4: Total Primary Energy Supply (left) **and Carbon Intensity of Energy** (right) **in Azerbaijan, Kazakhstan, and Uzbekistan (No Action Scenario through 2050)**



gCO_2e = grams of carbon dioxide equivalent, MJ = megajoule.

Sources: International Energy Agency. 2014. *World Energy Outlook*. http://www.oecd-ilibrary.org/energy/world-energy-outlook-2014_weo-2014-en; World Bank. World Development Indicators. Accessed March 2016 at http://data.worldbank.org/data-catalog/world-development-indicators; ADB. 2015b. *Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: The Economics of Reducing Greenhouse Gas Emissions in the Energy and Transport Sectors*. Consultant's report. Manila (TA 8119-REG).

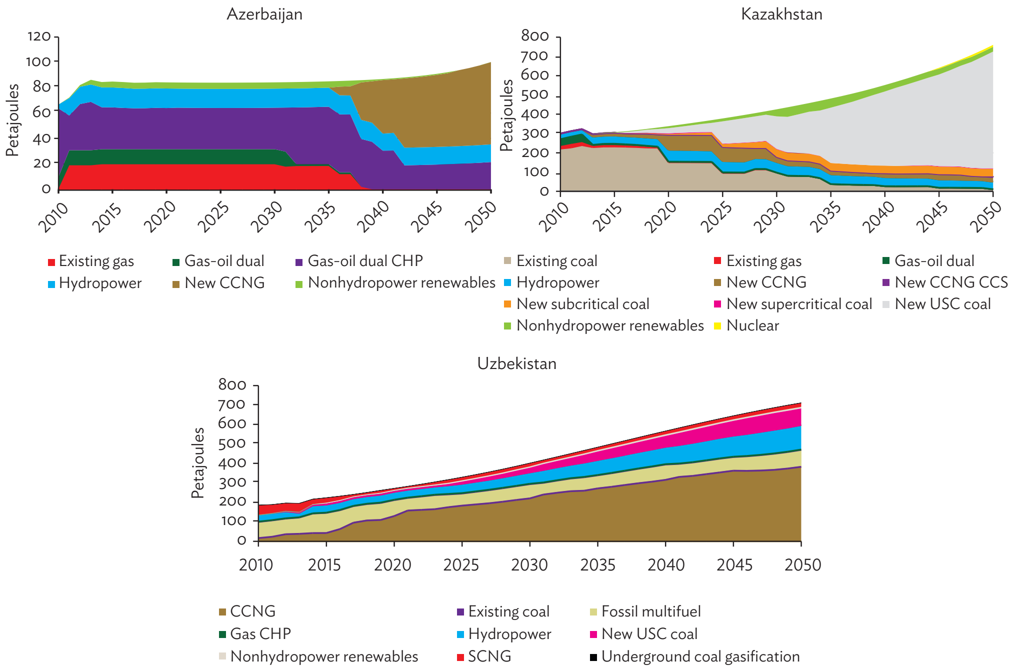
All three countries' energy intensity declined from 2000 to 2010, with Uzbekistan showing the most dramatic decline of 55.8% during that time period. Total primary energy supply (TPES) per capita increased in Kazakhstan but declined in Azerbaijan and Uzbekistan. The GHG intensity of TPES increased in Azerbaijan, declined in Kazakhstan, and remained unchanged in Uzbekistan. Azerbaijan, Kazakhstan, and Uzbekistan's hydrocarbon reserves have served as the engine for their recent economic growth, both as a source of export revenue and for meeting domestic energy demand.[11] Incorporating projections of population, GDP per capita, and energy intensity per unit of GDP yields the TPES projections in Figure 4A, which are expected to more than double or triple in all three countries. In each country, declining energy intensity is outweighed by rising population and income, and supply requirements' increase.

Overall TPES increased by 15%, due to growth in Kazakhstan. TPES in Azerbaijan declined by 3% and in Uzbekistan by 14%, due to significant energy efficiency improvements in both countries. Fossil fuels (coal, natural gas, and petroleum products) provide 99% of combined TPES for the study countries. Coal is the single largest energy source in Kazakhstan, while natural gas dominates in Azerbaijan and Uzbekistan. With energy requirements on the rise, the carbon intensity of energy assumes crucial importance. In the No Action Scenario, as Figure 4B illustrates, the overall carbon intensity of the energy supply is not projected to change significantly. Fundamentally, this is due to continued reliance on fossil fuels in buildings and for industry, transport, and power—oil and natural gas in Azerbaijan, oil and coal in Kazakhstan, and natural gas in Uzbekistan.

As of 2010, the total installed electricity generation capacity in the region was estimated at 38,468 megawatts (MW). The composition was approximately 40% natural gas, 38% coal, 8% oil, and 12% hydropower. In Kazakhstan, coal dominates power generation. In Azerbaijan and Uzbekistan, natural gas powers most of the electricity generation. From 2000 to 2010, there was a minor

[11] ADB. 2014a. *Economics of Climate Change in Central and West Asia - Mitigation Component: Inception Report.* Consultant's report. Manila (TA 8119-REG).

Figure 5: Projections of Electricity Production by Technology per Country (No Action Scenario)



CCNG = combined cycle natural gas, CCS = carbon capture and storage, CHP = combined heat and power, SCNG = simple cycle natural gas, USC = ultra-supercritical.

Source: ADB. 2015b. *Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: The Economics of Reducing Greenhouse Gas Emissions in the Energy and Transport Sectors*. Consultant's report. Manila (TA 8119-REG).

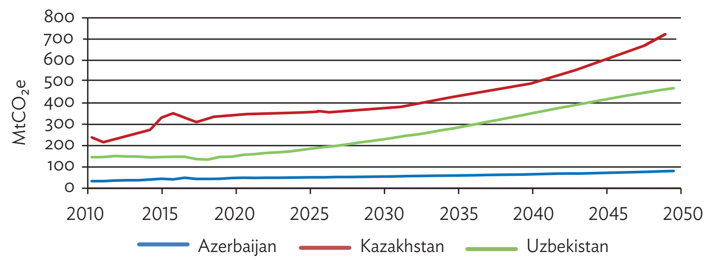
shift to renewables for power generation in Uzbekistan and a slight decrease in Azerbaijan and Kazakhstan.

The relative stability of the carbon intensity of energy is due to the underlying assumption within the No Action Scenario that no significant new mitigation policies are introduced. As shown in Figure 5, electricity production in each country continues to depend on fossil energy even after accounting for definitive short and medium-term capacity expansion plans. Modern fossil technologies (e.g., ultrasupercritical coal and contemporary combined cycle natural gas) gradually replace legacy technologies, but the overall reliance on fossil sources is not reduced.

Greenhouse Gas Emissions

The total GHG emissions grew in Azerbaijan and Kazakhstan from 2000 to 2010, while they declined in Uzbekistan. Figure 6 shows GHG emissions continuing to track upward in the absence of significant mitigation actions. From 2010 to 2050, total projected emissions rise 78% in Azerbaijan, 118% in Kazakhstan, and 243% in Uzbekistan. These increases have important implications for mitigation, simultaneously highlighting the need for mitigation effort and the growing potential to reduce fossil fuel emissions through efficiency, fuel switching, and other measures.

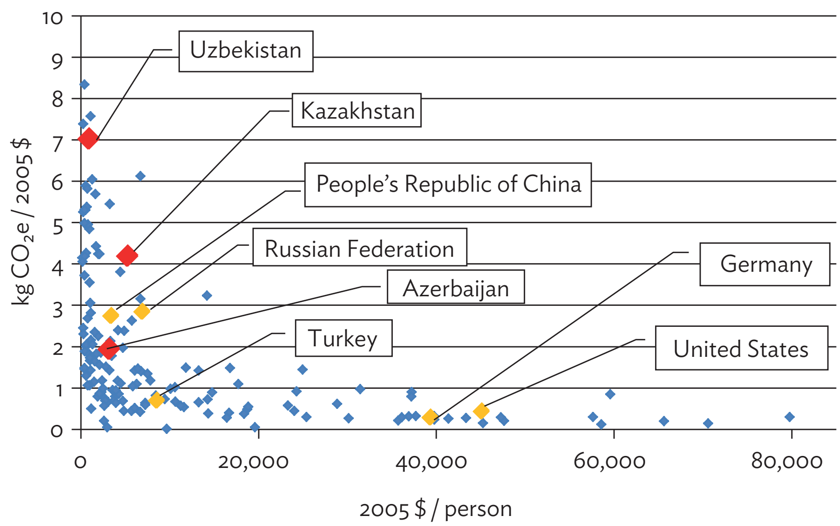
Figure 6: Projections of Total Greenhouse Gas Emissions through 2050 in Azerbaijan, Kazakhstan, and Uzbekistan under the No Action Scenario



$MtCO_2e$ = million tons of carbon dioxide equivalent.

Source: ADB. 2015b. *Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: The Economics of Reducing Greenhouse Gas Emissions in the Energy and Transport Sectors*. Consultant's report. Manila (TA 8119-REG).

Figure 7: Greenhouse Gas Intensity of Gross Domestic Product vs. Per Capita Income in 2012



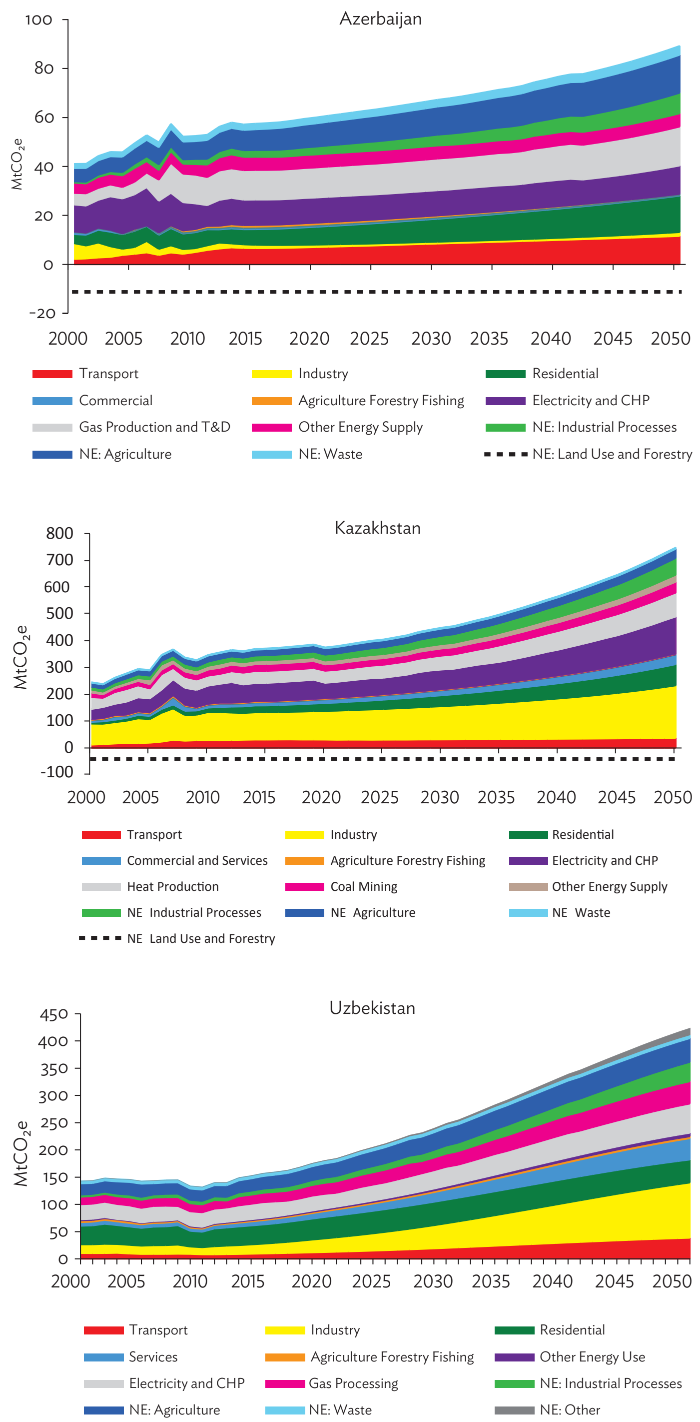
$kgCO_2e$ = kilograms of carbon dioxide emissions.

Sources: European Commission Joint Research Centre. Emissions Database for Global Atmospheric Research. Accessed March 2016 at http://edgar.jrc.ec.europa.eu; World Bank. World Development Indicators. http://data.worldbank.org/data-catalog/world-development-indicators

Even though the three countries account for a small fraction of global GHG emissions—about 1% of global carbon dioxide (CO_2) emissions in 2013[12]—when compared to countries with similar per capita income, all three show relatively high GHG intensity of GDP (Figure 7). Uzbekistan's and Kazakhstan's intensities are notably higher than Azerbaijan's (and the People's Republic of China's and the Russian Federation's, for example), while Azerbaijan's is somewhat lower but still

[12] European Commission Joint Research Centre. Emissions Database for Global Atmospheric Research. Accessed March 2016 at http://edgar.jrc.ec.europa.eu

Figure 8: Greenhouse Gas Emissions by Sector per Country (No Action Scenario, 100-Year Global Warming Potentials)



CHP = combined heat and power, $MtCO_2e$ = million tons of carbon dioxide equivalent, NE =non-energy, T&D = transmission and distribution.

Source: ADB. 2015b. *Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: The Economics of Reducing Greenhouse Gas Emissions in the Energy and Transport Sectors*. Consultant's report. Manila (TA 8119-REG).

greater than in nearby countries such as Turkey and Georgia. This is due to the continued reliance on fossil fuels—oil and natural gas in Azerbaijan, oil and coal in Kazakhstan, and natural gas in Uzbekistan—in buildings and for industry, transport, and power.

In all three countries, more than 75% of total 2010 GHG emissions are a result of activities in the energy and transport sectors (Figure 8). Energy-intensive industries are an important source of the GHG emissions in Kazakhstan and Uzbekistan, and fossil fuel production for export and domestic use contributes significant fugitive emissions in all three countries. In addition, the power sectors of Azerbaijan, Kazakhstan, and Uzbekistan remain dominated by fossil fuel technologies.

Greenhouse Gas Reduction Scenarios

A mitigation analysis for Azerbaijan, Kazakhstan, and Uzbekistan was undertaken, with a view to identifying a suite of greenhouse gas (GHG) abatement options and their corresponding cost per unit reduction in emissions. These emissions reductions are tested in mitigation scenarios, which share the same underlying growth drivers as the No Action Scenario. For this analysis, only a selected set of mitigation options is assessed in the Long-Range Energy Alternatives Planning (LEAP) model, chosen on the basis of their feasibility and appropriateness for each country's energy and transport sectors as well as availability of input data, following extensive stakeholder consultation and review of prevailing (and anticipated) government goals, policies, and targets. This would support the identification of investment options under the technical assistance (TA) that were not only cost-efficient but within the scope of politically feasible actions.

The full set of abatement options in each country is tabulated in Table 5, Table 7, and Table 9. These options were run in *pricing mitigation miniscenarios*, which reflected one discrete price-based mitigation option, such as a change in fuel or carbon prices; *technical mitigation miniscenarios*, which incorporate an additional discrete physical or behavioral mitigation option, such as a change in technology deployment, differential resource management practices, or the attainment of a nonprice target; and *combined mitigation scenarios*, which combine multiple technical miniscenarios into a portfolio of mitigation options.

The analysis indicates that in each country, there is a selection of technical mitigation measures with high mitigation potential that can be accessed at either a direct cost savings or a very low cost per ton of abatement. Efficiency improvements in buildings and vehicles fall into this category across the three countries, and in some cases, renewable energy options are also quite cost-effective. Many of the highest-cost measures contribute relatively little to the overall level of abatement that is achievable by the ensemble of mitigation options, suggesting that mitigation planning in the countries is indeed focused on cost-effective approaches. However, some options with a high cost per ton may still be worth considering if they advance other social goals, such as economic development (e.g., rail electrification in Azerbaijan and Uzbekistan), energy security and system reliability (e.g., rehabilitation of the national grid in Azerbaijan and Kazakhstan), or increased income generation in rural areas (e.g., biogas in Azerbaijan).

The study carried out an analysis of indirect cobenefits that can be achieved by implementing the mitigation measures, and included an assessment of reduced air pollutant emissions, human health benefits of reduced air pollution, and improved energy security. Several important indirect benefits to mitigation beyond the quantified GHG emission reductions are associated with the technical and pricing mitigation scenarios. Most noticeably, almost all of the analyzed mitigation scenarios result in fuel savings and improvement in the energy intensity of gross domestic product (GDP), particularly those that are based on energy efficiency improvements, introduce renewables, or use price-based signals to encourage less energy consumption. This means that introducing mitigation measures in the energy and transport sectors also tends to improve energy security.

Costs and Benefits of Abatement Options in Azerbaijan

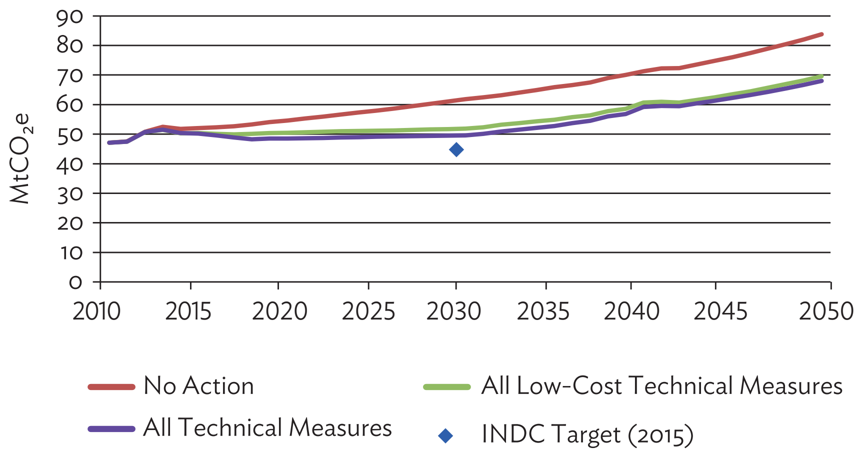
Direct Costs of Abatement and Corresponding Greenhouse Gas Reductions

The analysis of direct costs and benefits of mitigation considers two primary questions: the mitigation potential (tons of carbon dioxide equivalent [tCO_2e] reduced) and the cost-effectiveness (direct cost per tCO_2e reduced) of each mitigation option, taking into account capital, operations and maintenance, fuel, and program implementation costs (i.e., operational expenses). Focusing on these costs (and benefits, in the case of net cost reductions) helps identify options that provide the greatest abatement return for society's direct investment.

To show the overall effect of abatement on the country's GHG emissions, total anticipated GHG emissions under a scenario that implements all technical measures are depicted against the No Action Scenario (Figure 9). Furthermore, total country emissions for implementing only low-cost options (i.e., whose cumulative [through 2050] discounted cost per tCO_2e abated is less than or equal to 2010 $10) are also shown, for additional comparison.

The portfolio of technical mitigation options for Azerbaijan results in significant abatement by 2050—around 13% versus the No Action Scenario for all technical measures. The analysis suggests that most of the mitigation potential found in each country is low cost or result in overall savings to the country. For example, implementing all the low-cost technical measures analyzed for Azerbaijan can be done at a cost of $-4.9 per tCO_2e (Table 5). Adding the higher cost options that were analyzed provide only modest abatement gains; the absence of

Figure 9: Impact of Mitigation Options on Greenhouse Gas Emissions in Azerbaijan



INDC = Intended Nationally Determined Contribution, $MtCO_2e$ = million tons of carbon dioxide equivalent.
Source: ADB. 2015b. *Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: The Economics of Reducing Greenhouse Gas Emissions in the Energy and Transport Sectors*. Consultant's report. Manila (TA 8119-REG).

institutional incentives resulting in high capital and operational costs of implementation. In addition, other considerations beyond financial savings play a role in determining if a mitigation option would be taken further, including whether or not institutional enabling mechanisms exist for implementation, the absence of policies on incentives in green investment, and relative experience in newer technologies.

In Azerbaijan, several of the price-based carbon tax scenarios result in a higher amount of cumulative GHG abatement than if all low-cost technical measures were implemented, albeit at a slightly higher cost. Similarly, if Azerbaijan were to equalize fossil fuel prices with those of countries in the Organisation for Economic Co-operation and Development (OECD) by 2030, the country can achieve a 36% reduction in GHG emissions by 2050 as compared to the No Action Scenario. This can be done at a cost of $7 per tCO_2e. This indicates that there are several additional low cost mitigation options available to Azerbaijan, beyond those analyzed in this TA, which the government can incorporate into its development plans. For example, due to lack of data, this study does not analyze mitigation measures targeting fugitive emissions from oil and gas production although there is significant potential for reducing emissions from this sector.

Nevertheless, the ensemble of technical mitigation options is able to keep emissions in check in the short to medium-term—through about 2025 or 2030. However, in the long run, the analyzed mitigation options will not be able to prevent emission increases, with total emissions in 2050 expected to be greater than in 2010 even when all of the evaluated mitigation options are deployed. This is because fundamental dependencies on fossil fuels remain in place in buildings, industry, transport, and, to a lesser extent, power generation. Energy efficiency measures and switching to natural gas are a solution in the short term, but are ultimately outweighed by projected increases in population, economic activity, and affluence. These factors drive greater total demand for energy in the still carbon-dependent energy and transport systems.

Table 5: Direct Costs and Abatement Potential for Mitigation Options in Azerbaijan

Technical Mitigation Miniscenarios (Cumulative through 2050 Using Retrospective Systems Analysis)					
Scenario Name	**Sector**	**Description**	**Cumulative Potential GHG Emission Reductions** (tCO_2e)	**Discounted Reduction Cost per Ton** (2007 AZN/ tCO_2e)	**Discounted Reduction Cost per Ton** (2010 \$/tCO_2e)
Euro-4 Vehicle Standards	Transport	Implementation of Euro-4 standards for all new light and medium duty passenger vehicles, beginning in 2014. Based on Posada Sanchez et al. (2012) and other sources.	12,301,298	–47.7	–70.2
SOCAR Eco-driving	Transport	Implementation of an ecodriving program for SOCAR's vehicle fleet, beginning in 2015. Based on UNDP (2014a).	1,926,241	–43.2	–63.6
Commercial CFL Lighting	Commercial/ Services	By 2030, all light bulbs in commercial establishments are high-efficiency compact fluorescent bulbs. Based on Ministry of Ecology and Natural Resources of Azerbaijan Republic (2012).	44,199,773	–6.3	–9.3
Residential CFL Lighting	Residential	By 2030, all light bulbs in both urban and rural households are high-efficiency compact fluorescent light (CFL) bulbs, using 75% less energy than incandescent bulbs. Based on Ministry of Ecology and Natural Resources of Azerbaijan Republic (2012).	76,763,797	–5.8	–8.5
Forests 20% of Total Land Area	Non-Energy	Forested area increases to 20% of total land area by 2050. Based on Ministry of Ecology and Natural Resources of Azerbaijan Republic (2013).	45,706,558	0.5	0.8
Forests 12.5% of Total Land Area	Non-Energy	An increase in forested area during 2008–2015 to 12.5% of total land area. Based on President of the Republic of Azerbaijan (2008).	8,466,758	0.9	1.3

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Table 5 continued

Technical Mitigation Miniscenarios (Cumulative through 2050 Using Retrospective Systems Analysis)					
Scenario Name	**Sector**	**Description**	**Cumulative Potential GHG Emission Reductions** (tCO_2e)	**Discounted Reduction Cost per Ton** (2007 AZN/ tCO_2e)	**Discounted Reduction Cost per Ton** (2010 \$/tCO_2e)
Improved Insulation	Residential	Insulation upgrades in 20% of urban residential buildings by 2050. Heat losses in upgraded buildings are about half of those in existing urban residential buildings. Based on Aliyev (2013).	72,144,742	1.0	1.5
Small Hydro	Electricity Production	164 new small hydroelectricity plants averaging 2 MW apiece are constructed by 2030. Based on Ministry of Ecology and Natural Resources of Azerbaijan Republic (2012).	33,939,169	1.3	1.9
Sustainable Land Management	Non-Energy	Pilot projects to improve management of and rehabilitate forests and pasture land, affecting approximately 47,000 hectares. Based on UNDP (2011).	12,052,454	2.2	3.3
Onshore Wind	Electricity Production	Build-out of onshore wind power capacity to 800 MW by 2050. Based on Ministry of Ecology and Natural Resources of Azerbaijan Republic (2012).	15,534,982	5.8	8.5
Samukh Agro-Energy Complex	Agriculture/ Residential	Construction of the Samukh Agro-Energy Complex including 6 MW of solar photovoltaic and 0.75 MW of biogas power, as well as 0.75 MW of biogas, 0.6 MW of geothermal, and 6 MW of solar thermal heat capacity by 2016. Following the initial deployment, an additional 14 MW of solar photovoltaic and 7.25 MW of biogas power, as well as 7.25 MW of biogas, 2.4 MW geothermal and 32 MW of solar thermal heat capacity come online by 2020. All heat and power is consumed locally by the agricultural and residential sectors.	4,074,171	6.8	10.0

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Table 5 continued

Technical Mitigation Miniscenarios (Cumulative through 2050 Using Retrospective Systems Analysis)					
Scenario Name	**Sector**	**Description**	**Cumulative Potential GHG Emission Reductions** (tCO_2e)	**Discounted Reduction Cost per Ton** (2007 AZN/ tCO_2e)	**Discounted Reduction Cost per Ton** (2010 \$/tCO_2e)
Renewable Power Target[a]	Electricity Production	Models renewable generation and capacity targets for 2020 described in IEA and IRENA (2014), including short term plans from the State Agency for Alternative and Renewable Energy Sources of the Republic of Azerbaijan (2014). • Renewable sources must provide at least 20% of generated electricity; and • At least 2,000 MW of renewable electricity capacity must be installed.	32,550,700	24.2	35.6
3 MW Small Solar	Electricity Production	Construction of an additional 3 MW of distributed solar electricity capacity by 2030. Based on Ministry of Ecology and Natural Resources of Azerbaijan Republic (2012).	93,009	28.6	42.0
Municipal Solid Waste to Energy	Electricity Production	New waste-to-energy (WtE) capacity is deployed to maintain the diversion of 25% of municipal solid waste to WtE plants through 2050 (currently, about 25% of municipal solid waste is diverted to the Baku WtE plant). Based on UNFCCC CDM Executive Board (2012a).	4,751,891	56.5	83.1
Biogas	Residential	Installation of biogas digesters in rural areas not supplied with natural gas. Assumes that 10% of rural households have biogas by 2030, and that the energy supplied is used for heating and cooking. Based on The Republic of Azerbaijan (2013).	1,963,020	124.2	182.7

[a] The Renewable Power Target Scenario is actually a combined mitigation scenario (it combines SAARES's short-term plans with renewable power targets for 2020), but it is included with the technical scenarios because it was evaluated using the retrospective systems method.

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Table 5 continued

Technical Mitigation Miniscenarios (Cumulative through 2050 Using Retrospective Systems Analysis)					
Scenario Name	**Sector**	**Description**	**Cumulative Potential GHG Emission Reductions** (tCO_2e)	**Discounted Reduction Cost per Ton** (2007 AZN/ tCO_2e)	**Discounted Reduction Cost per Ton** (2010 \$/tCO_2e)
Electricity Network Upgrade	Electricity Production	Electricity transmission and distribution (T&D) losses are reduced to 10% by 2050. The improvement affects both existing and newly constructed T&D lines. Based on Energy Charter Secretariat (2013) and ADB (2008).	20,107,941	236.2	347.3
AC Rail Conversion	Transport	Conversion to alternating current (AC) of all electrified rail existing in the No Action Scenario, which is assumed to be entirely direct current (DC). Full implementation is anticipated by 2050. Based on World Bank (2013b) and other sources.	529,352	325.0	477.8
Solar Hot Water	Residential	Installation of solar hot water systems in rural households to reduce demand for conventional fuels. Assumes that 25% of rural households have such systems by 2050. Based on The Republic of Azerbaijan (2013).	1,416,631	379.5	558.0
Efficient Stoves	Residential	Efficient liquefied petroleum gas and wood cook stoves are installed in rural households not supplied with natural gas. Assumes that 10% of rural households have such stoves by 2030. Based on The Republic of Azerbaijan (2013).	196,768	773.9	1,137.8
Rail Electrification	Transport	AC electrification of railways that are not electrified in the No Action Scenario. Full implementation is expected by 2050. Based on World Bank (2013a) and other sources.	91,026	909.4	1,337.1
SAARES Short-Term Plans	Electricity Production	New capacity targets for large and small hydro, onshore wind and utility-scale photovoltaic plants from 2015 – 2018. Targets are provided by the State Agency for Alternative and Renewable Energy Sources (SAARES) of the Republic of Azerbaijan.	0	NA*	NA*

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Table 5 continued

Pricing Scenarios (Cumulative Through 2050 Relative to the No Action Scenario)						
Scenario	**Sector**	**Description**	**Cumulative Potential GHG Emission Reductions** (tCO_2e)	**Percent Change by 2050 Relative to No Action Scenario** (%)	**Discounted Reduction Cost per Ton** (2007 AZN/tCO_2e)	**Discounted Reduction Cost per Ton** (2010 \$/tCO_2e)
Carbon Tax (Low)	All sectors	Implementation of the following gradual carbon tax schedule (all taxes in 2010 $): \$5 by 2015, \$15 by 2020, \$25 by 2030, and \$50 by 2050. Based on Abt Associates et al. (2014a).	449,401,278	-14.9	3.0	4.4
Carbon Tax (Moderate)			517,191,771	-17.1	3.3	4.8
Carbon Tax (EU Harmonization)			549,828,236	-18.2	3.5	5.2
Fossil Subsidy Removal	All sectors	Price subsidies for fossil fuels and derived secondary fuels are phased out by 2030. Based on subsidy rates reported in IEA (2014b).	575,454,155	-19.1	5.0	7.4
OECD Fuel Prices	All sectors	Prices for major fuels equalize with current (2013) OECD averages by 2030. Based on IEA (2014a).	1,103,806,342	-36.6	5.2	7.7

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Table 5 continued

Combined Mitigation Scenarios (Cumulative Through 2050 Relative to the No Action Scenario)						
Scenario			**Cumulative Potential GHG Emission Reductions** (tCO_2e)	**Percent Change by 2050 Relative to No Action Scenario** (%)	**Discounted Reduction Cost per Ton** (2007 AZN/ tCO_2e)	**Discounted Reduction Cost per Ton** (2010 \$/ tCO_2e)
State Program of Poverty Reduction	All sectors	Models a selection of measures and targets given in President of the Republic of Azerbaijan (2008). Includes: Double GDP per capita during 2008–2015; During 2008–2015, increase forested area to 12.5% of total land area; and During 2006–2015, decrease fuel combustion (conditional fuel spent/kWh) in electricity production by 20%.	-479,774,029	15.9	NA*	NA*
All Low-Cost Technical Measures	All sectors	A combined scenario including all technical miniscenarios whose cumulative discounted direct cost per ton of GHG reductions <= 10 2010 $.	327,109,943	–10.8	–3.4	–4.9
All Moderate-Cost Technical Measures	All sectors	A scenario quantifying potential moderate-cost technical mitigation options for Azerbaijan. Includes all individual mitigation options whose cumulative discounted direct cost per ton of GHG reductions <= 50 2007 AZN.	359,753,652	–11.9	–0.9	–1.3
All Technical Measures	All sectors	A combined scenario including all technical miniscenarios showing abatement potential.	388,810,279	–12.9	15.2	22.3

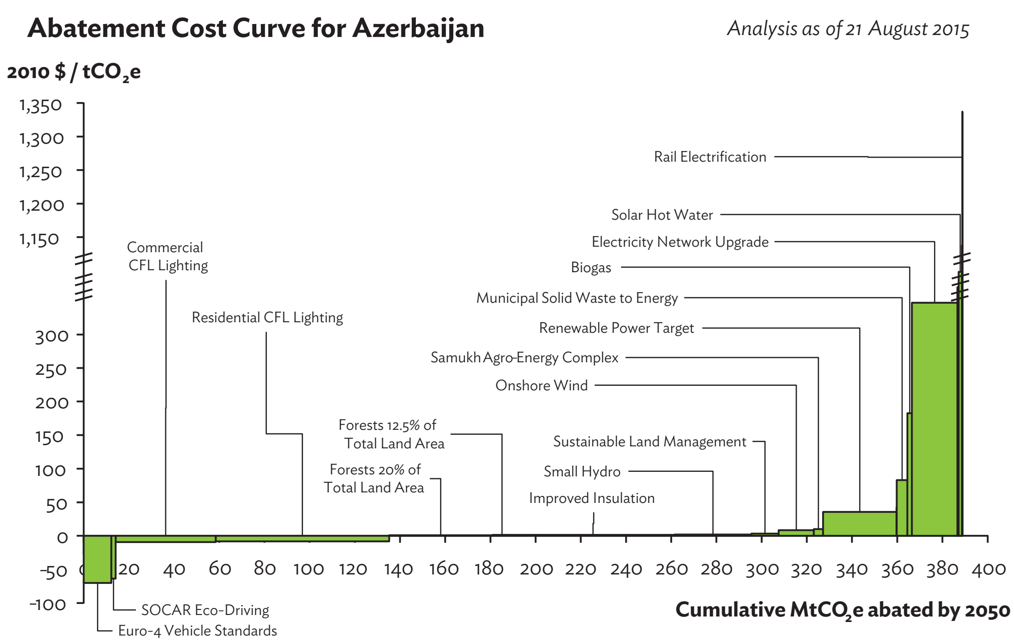
AZN = Azerbaijan manat, CDM = Clean Development Mechanism, EU = European Union, GDP = gross domestic product, GHG = greenhouse gas, IEA = International Energy Agency, kWh = kilowatt hour, MW = megawatt, OECD = Organisation for Economic Co-operation and Development, SOCAR = State Oil Company of the Azerbaijan Republic, tCO_2e = ton of carbon dioxide equivalent, UNDP = United Nations Development Programme, UNFCCC = United Nations Framework Convention on Climate Change.

Note: * Miniscenarios marked "NA" have undefined abatement costs since they result in increased or unchanged emissions. In many cases (e.g., the Renewable Power Target scenario in Azerbaijan), this result is due to interactions with miniscenarios ranked higher in the retrospective systems order.

Source: ADB. 2015b. *Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: The Economics of Reducing Greenhouse Gas Emissions in the Energy and Transport Sectors.* Consultant's report. Manila (TA 8119-REG).

The abatement potential and costs of options evaluated can be represented visually in a *marginal abatement cost curve* (MACC). Such a curve is composed of a series of segments for the mitigation options that are explored—the width represents the total abatement potential of an option, while the height describes the option's cost-effectiveness. The segments are then aligned in order of increasing cost per ton. The widths of segments can be added to determine the total mitigation potential at a given cost (Figure 10). As an illustrative guide, MACCs offer a simple and attractive tool for policy makers and researchers because they are straightforward to use and directly present a cost related to certain emission reduction target.[13] However, they should not be relied on exclusively for policy decisions, since due to their simplistic nature, they generally fail to capture interactions, consideration of ancillary benefits and externalities, effective treatment of uncertainties and representation of cumulative emission abatement to address time-related interactions.[14]

Figure 10: Marginal Abatement Cost Curve of Technical Mitigation Miniscenarios in Azerbaijan



CFL = compact fluorescent light, $MtCO_2e$ = million tons of carbon dioxide equivalent, SOCAR = State Oil Company of the Azerbaijan Republic.

Source: ADB. 2015b. *Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: The Economics of Reducing Greenhouse Gas Emissions in the Energy and Transport Sectors*. Consultant's report. Manila (TA 8119-REG).

[13] E. D. Delarue, A. D. Ellerman, and W. D. D'haeseleer. 2009. Robust MACCs? The topography of abatement by fuel switching in the European power sector. *Energy*. 35 (3). pp. 1465–1475. http://www.sciencedirect.com/science/article/pii/S0360544209005234

[14] F. Kesicki and N. Strachan. 2011. Marginal abatement cost (MAC) curves: confronting theory and practice. *Environmental Science & Policy*. 14 (8). pp. 1195–1204. http://www.sciencedirect.com/science/article/pii/S1462901111001377

Indirect Cobenefits of Greenhouse Gas Mitigation

Indirect cobenefits can be achieved by implementing the mitigation options analyzed in this study; these included reduced air pollutant emissions, human health benefits of reduced air pollution, and improved energy security (Table 6). Focusing on these indirect results of GHG mitigation helps improve the overall benefits that may be derived from the mitigation options examined.

Analysis of cobenefits indicates that, overall, the mitigation options in Azerbaijan produce relatively modest impacts on human health, with the largest impact of 242 avoided mortalities observed under the OECD Fuel Price scenario. The Fossil Subsidy Removal option, along with the three Carbon Tax options and Potential Intended Nationally Determined Contribution (INDC), also generate avoided mortalities greater than 100; however, over the 40-year period of 2010–2050 these are modest impacts. Other mitigation options generate relatively insignificant impact to human health, and in two cases (Waste to Energy, and State Program of Poverty Reduction) we observe small increases in incidence of mortality. With respect to energy security, the same options that produce the largest human health benefits also produce the overall largest improvements in energy security. For example, the OECD Fuel Price scenario indicates an approximately 65% decrease in energy and carbon intensity, with a corresponding 346% increase in the share of renewable energy in total primary energy supply. As with human health, the Carbon Tax and Potential INDC options also produce significant energy security benefits, indicated by the decreases in energy and carbon intensity, and increase in renewable energy use.

In Azerbaijan, the most attractive technical mitigation options in terms of fuel savings are residential and commercial compact fluorescent light (CFL) lighting, improved insulation, the 2020 renewable power targets, the State Agency on Alternative and Renewable Energy Sources (SAARES) short-term plan, and upgrades to the electricity network.

Overall, the price-based mitigation scenarios are the most effective at reducing fuel consumption. In Azerbaijan, the scenario based on aligning domestic fuel prices with OECD prices results in cumulative savings of 14,370 gigajoules by 2050, which is far more than if all the technical mitigation measures are implemented. Similarly, the three carbon tax scenarios result in greater fuel savings than the combined technical mitigation measures. This result is driven by differences in the prices for key fuels in Azerbaijan, which increase a lot more in the OECD price scenario than in the carbon tax scenarios. For example, depending on the year, the price of natural gas is 70%–80% higher in the OECD scenario than in the Carbon Tax (European Union Harmonization) scenario; the prices of gasoline and diesel are 40%–50% higher; the price of LPG is 70%–80% higher. Higher prices depress demand relative to the carbon tax scenarios and lead to greater fuel savings. Similarly, the three carbon tax scenarios result in greater fuel savings than the combined technical mitigation measures, which affect certain parts of the energy system rather than the whole; the broad applicability of the carbon price means that it touches a number of sectors and subsectors that are not changed in all technical mitigation scenarios, particularly on the demand side of the energy system.

Table 6: Energy Security and Human Health Cobenefits of Mitigation in Azerbaijan (Cumulative Impacts by 2050 Relative to the No Action Scenario)

	Energy Security							Human Health	
	Cumulative Avoided Mortalities	Monetized Value of Avoided Mortalities (2010 $)		Carbon Intensity of GDP (percent change, %)		Renewable Energy Percentage in Primary Energy Supply (percent change, %)		Cumulative Avoided Mortalities	Monetized Value of Avoided Mortalities (2010 $)
Mitigation Option	2010–2050	2010–2050	2050	2020	2010–2050	2010–2050	2050	2010–2050	2010–2050
Technical Mitigation Miniscenarios									
Euro-4 Vehicle Standards	22	$3,055,547	−0.90	−0.30	−0.90	0.30	0.90	22	$3,055,547
SOCAR Eco-driving	1	$103,649	−0.10	−0.10	−0.10	0.10	0.10	1	$103,649
Commercial CFL Lighting	22	$3,546,868	−3.20	−1.00	−3.00	1.10	3.30	22	$3,546,868
Residential CFL Lighting	36	$5,877,731	−5.20	−1.70	−4.90	1.90	5.50	36	$5,877,731
Forests 20% of Total Land Area	0	$0	0.00	0.00	0.00	0.00	0.00	0	$0
Forests 12.5% of Total Land Area	0	$0	0.00	0.00	0.00	0.00	0.00	0	$0
Improved Insulation	11	$1,883,886	−6.90	−1.60	−6.30	1.80	7.40	11	$1,883,886
Small Hydro	14	$3,248,360	−0.30	−1.40	−0.50	10.70	8.30	14	$3,248,360
Sustainable Land Management	0	$0	0.00	0.00	0.00	0.00	0.00	0	$0
Onshore Wind	6	$465,213	−1.40	0.00	−2.20	0.00	35.20	6	$465,213
Samukh Agro-Energy Complex	1	$250,040	−0.10	−0.30	−0.20	3.40	4.50	1	$250,040
2020 Renewable Power Targets	18	$4,114,261	−1.10	−3.40	−1.70	28.10	27.50	18	$4,114,261
3 MW Small Solar	0	$7,666	0.00	0.00	0.00	0.00	0.00	0	$7,666
Municipal Solid Waste to Energy	−14	−$1,899,378	1.70	−0.20	−0.40	14.00	76.40	−14	−$1,899,378
Biogas	1	$159,690	−0.10	−0.10	−0.10	0.00	−0.20	1	$159,690
Electricity Network Upgrade	13	$2,059,867	−2.60	−0.70	−2.40	0.80	2.70	13	$2,059,867

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Table 6 continued

Mitigation Option	Energy Security							Human Health	
	Cumulative Avoided Mortalities	Monetized Value of Avoided Mortalities (2010 $)		Carbon Intensity of GDP (percent change, %)		Renewable Energy Percentage in Primary Energy Supply (percent change, %)		Cumulative Avoided Mortalities	Monetized Value of Avoided Mortalities (2010 $)
	2010–2050	2010–2050	2050	2020	2010–2050	2010–2050	2050	2010–2050	2010–2050
AC Rail Conversion	0.3	$30,210	–0.10	0.00	–0.10	0.00	0.10	0.3	$30,210
Solar Hot Water	0.2	$42,139	–0.10	0.00	–0.10	0.00	0.00	0.2	$42,139
Efficient Stoves	0	$0	0.00	0.00	0.00	–0.10	–0.60	0	$0
Rail Electrification	0.1	$4,810	0.00	0.00	0.00	0.00	0.00	0.1	$4,810
SAARES Short-Term Plan	16	$3,997,387	–0.20	–3.40	–0.30	28.10	4.50	16	$3,997,387
Pricing and Combined Mitigation Scenarios									
Carbon Tax (Low)	130	$21,424,289	–36.90	–12.20	–38.30	51.50	260.80	130	$21,424,289
Carbon Tax (Moderate)	147	$23,931,503	–42.10	–14.90	–43.20	55.70	286.70	147	$23,931,503
Carbon Tax (EU Harmonization)	155	$25,652,998	–42.20	–16.90	–43.30	59.10	287.60	155	$25,652,998
Fossil Subsidy Removal	165	$25,836,142	–37.90	–14.30	–40.70	34.50	267.50	165	$25,836,142
OECD Fuel Prices	242	$44,814,480	–65	–52.80	–64.30	153.30	346.10	242	$44,814,480
State Program of Poverty Reduction	–44	–$17,835,647	–25.70	–5.40	–23.90	–5.80	8.60	–44	–$17,835,647
All Low-Cost Technical Measures	110	$18,662,070	–18.05	–7.26	–18.01	24.90	77.93	110	$18,662,070
All Moderate-Cost Technical Measures	128	$22,042,095	–18.20	–10.70	–18.30	54.10	83.60	128	$22,042,095
All Technical Measures	120	$21,627,499	–18.64	–11.63	–20.56	69.38	180.80	120	$21,627,499

AC = alternating current, CFL = compact fluorescent light, EU = European Union, GDP = gross domestic product, MW = megawatt, OECD = Organisation for Economic Co-operation and Development, SAARES = Azerbaijan State Agency for Alternative and Renewable Energy Sources, SOCAR = State Oil Company of the Azerbaijan Republic.

Note: Costs are discounted using a 7% real discount rate.

Source: ADB. 2015b. *Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: The Economics of Reducing Greenhouse Gas Emissions in the Energy and Transport Sectors.* Consultant's report. Manila (TA 8119-REG).

Costs and Benefits of Abatement Options in Kazakhstan

Direct Costs of Abatement and Corresponding Greenhouse Gas Reductions

The cost-benefit analysis indicates that in Kazakhstan, a selection of technical mitigation measures exists that have a high GHG abatement potential and accessible at either a direct cost savings or at a very low cost per ton of abatement. These are particularly attractive measures, and include the introduction of compressed natural gas (CNG) vehicles, improved heat pump insulation, coalbed methane capture, and efficient new homes in Kazakhstan. The natural gas power target, the alternative power target, a CO_2 cap on power generation, the emission trading scheme (ETS), and several energy efficiency measures are also low in cost and will result in significant emission reductions if implemented. Recognizing this potential for significantly reducing emissions at a low to no cost (Figure 11), the government of Kazakhstan is moving ahead with the Green Growth Concept which establishes an overall framework for their implementation.

The portfolio of technical mitigation options for Kazakhstan results in significant abatement; technical options are able to achieve approximately 20% abatement compared to the No Action Scenario (Figure 12). The CNG Fleet and CNG Passenger Cars Scenarios show the lowest abatement cost of all measures explored in Kazakhstan. Significant GHG emissions reductions are also able to be realized from improvements in heating, as presented by the scenarios on improved heat pipe insulation and construction of efficient new homes, both of which would yield a cumulative GHG reduction of over 400 million tons by 2050 or 14% of total abatement from all technical measures, at a cost savings.

The price-based mitigation measures analyzed for Kazakhstan, such as emissions trading and removal of fossil fuel subsidies, result in a 5%–7% reduction in cumulative emissions by 2050 compared to the No Action Scenario, which is about half as much as if all the low-cost technical mitigation measures are implemented (13%). This indicates that Kazakhstan is already planning to implement measures that will result in considerable emission reductions, such as switching away from coal for power generation and improving the efficiency of energy use for buildings.

Indirect Cobenefits of Greenhouse Gas Mitigation

The largest overall cobenefits in Kazakhstan are produced by the Extended Emission Trading Scheme, and the alternate version of the ETS (Table 8). Public health benefits for these options are in the order of 5,500–5,800 avoided mortalities (or, about 135–145 per year). These options also show some decrease in energy intensity and carbon intensity, and significant increases in renewable energy in the energy supply in 2020 and 2050. The CO_2 Cap on Power options produce similar effects with respect to energy security, but slightly lower human health benefits of about 1,000–1,200 cumulatively through 2050. Other mitigation options produce few human health benefits, and have mixed or lower benefits for energy security overall. For example, the Natural Gas Power Target scenarios show improvements in energy security over the long-run, by 2050, but show increases in energy and carbon intensity and a reduction of renewable energy use in the short-run, by 2020.

Table 7: Direct Costs and Abatement Potential for Mitigation Options in Kazakhstan

Technical Mitigation Miniscenarios (Cumulative through 2050 Using Retrospective Systems Analysis)					
Scenario	**Sector**	**Description**	**Cumulative Potential GHG Emission Reductions** (tCO_2e)	**Discounted Reduction Cost per Ton** (2010 KZT/ tCO_2e)	**Discounted Reduction Cost per Ton** (2010 \$/tCO_2e)
CNG Fleet	Transport	Sales of 325,000 cars, 45,000 buses and 60,000 trucks by 2025, to meet CNG conversion targets displacing sales of gasoline and diesel vehicles which would otherwise occur.	27,295,626	–12,170.7	–82.6
CNG Passenger Cars	Transport	Integration of an additional 3000 Euro M1 category compressed natural gas (CNG) passenger vehicles by 2015, rising to 50,000 vehicles beyond the No Action Scenario by 2018. Based on information from NGV Global (2010).	1,453,274	–2,786.3	–18.9
Improved Heat Pipe Insulation	Residential	Improvement of internal (in-building) heat pipe insulation in urban households, beginning with 1200 urban apartment buildings by 2020, and reaching all currently existing urban households by 2040. Costs and energy savings from Ergonomika (2011).	166,006,789	–292.3	–2.0
Coalbed Methane Capture	Industrial	Expansion of small-scale heat and power generation projects from coal mine methane (CMM) capture, for consumption by local mining operations. Based on a project described by US EPA (2013b).	94,167,987	–139.5	–0.9
Efficient New Homes	Residential	Six million square meters of newly-constructed residential space that meet heating efficiency standards are added each year through 2020, from the Ministry of Environment and Water Protection of the Republic of Kazakhstan (2013). Following this period, all additional new urban households are assumed to meet the same standard. Costs and energy savings from UNDP (2014c).	238,762,921	–43.4	–0.3
Natural Gas Power Target (Green Growth)	Electricity Production	Total natural gas power generation reaches 20% by 2020, 25% by 2030 and 30% by 2050, as described by the President of the Republic of Kazakhstan (2013).	399,039,208	337.0	2.3

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Table 7 continued

Technical Mitigation Miniscenarios (Cumulative through 2050 Using Retrospective Systems Analysis)					
Scenario	**Sector**	**Description**	**Cumulative Potential GHG Emission Reductions** (tCO_2e)	**Discounted Reduction Cost per Ton** (2010 KZT/ tCO_2e)	**Discounted Reduction Cost per Ton** (2010 $/$tCO_2e$)
Internal Heating Network Improvements	Residential	Improvement of internal heating distribution network in urban households, beginning with 1,200 urban apartment buildings by 2020, and reaching all currently existing urban households by 2040. Specific measures include introducing thermostatic and pressure balancing values, heat meters and hot water heat exchangers. Costs and energy savings from Ergonomika (2011).	404,198,552	507.4	3.4
CO_2 Cap on Power (Green Growth)	Electricity Production	Implementation of an emissions cap on carbon dioxide from electricity generation: -3% by 2015, -7% by 2020, -15% by 2030, and -40% by 2050, relative to 2012 emissions. Based on Abt Associates et al. (2014a).	673,820,538	558.4	3.8
Improved Insulation	Residential	Improvement of insulation in urban residential walls and ceilings, beginning with 1,200 urban apartment buildings by 2020, and reaching all currently existing urban households by 2040. Costs and energy savings from Ergonomika (2011).	395,591,779	1,007.6	6.8
Advanced Windows	Residential	Replacement of inefficient windows in urban households using windows with a higher insulation value, beginning with 1,200 urban apartment buildings by 2020, and reaching all currently existing urban households by 2040. Costs and energy savings from Ergonomika (2011).	77,757,249	1,808.7	12.3
Heat Distribution Upgrades	Heat Production	Renovation of highly worn sections of the district heating distribution network, reducing losses from 36% to 6% (or 17.1%, when viewed in aggregate for the entire national heating network), as described by Ministry of Regional Development (2014).	159,352,071	2,877.4	19.5
Alternative Power Target	Electricity Production	Total alternative power generation (includes both renewables and nuclear) reaches 3% by 2020, 30% by 2030, and 50% by 2050, as described by the President of the Republic of Kazakhstan (2013).	217,505,879	4,457.0	30.2

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Table 7 continued

Technical Mitigation Miniscenarios (Cumulative through 2050 Using Retrospective Systems Analysis)					
Scenario	**Sector**	**Description**	**Cumulative Potential GHG Emission Reductions** (tCO_2e)	**Discounted Reduction Cost per Ton** (2010 KZT/ tCO_2e)	**Discounted Reduction Cost per Ton** (2010 \$/tCO_2e)
Expanded + Optimistic Nuclear Power[2]	Electricity Production	Total installed nuclear generation capacity reaches 1.5 GW by 2030 and 2.0 GW by 2050, as described by the President of the Republic of Kazakhstan (2013). In addition to nuclear capacity that is introduced in the No Action Scenario (900 MW by 2030), an additional 1,800 MW of capacity is brought online in 2023 in Kurchatov, based on input from national partners.	38,826,060	4,771.7	32.4
Rehabilitation of National Grid	Electricity Production	This measure aims to reduce electrical transmission losses to 6% by 2040, implemented in two phases. The first phase rehabilitates 2,604 km of existing transmission line by 2020, followed by the second phase which rehabilitates the remainder of currently existing transmission line stock by 2040. Based on energy efficiency plans described by ADB (2011), and input from national partners.	21,979,657	13,991.4	95.0
Urban LED Lighting	Commercial/ Services	Upgrading of inefficient sodium lighting to new LED technology, in outdoor public spaces. The measure initially covers only Almaty through 2021 according to UNDP (2014b), before expansion to all urban areas by 2030.	459,737	19,499.8	132.3
Waste to Energy	Electricity Production	Transformation of municipal solid waste (MSW) to electricity in waste-to-energy plants, consuming 5% of MSW generated in Almaty by 2020, and 30% of MSW in Almaty by 2050. Based on plans described by Mitsubishi Heavy Industries et al. (2014).	–142,956	NA*	NA*
Euro-5 Vehicles	Transport	Beginning in 2016, only vehicles adhering to Euro-5 standards may be sold. Based on Dzhaylaubekov (2014).	–10,237,033	NA*	NA*
Early Vehicle Retirement	Transport	The President of the Republic of Kazakhstan (2014) sets a target to retire 80% of all vehicles on the road in 2014, by the year 2030. This measure assumes the gradual scrappage across all vehicle categories of Euro 0, 1, 2, and 3-compliant vehicles that were in operation in the year 2014, and their replacement with new vehicles.	–31,179,955	NA*	NA*

continued on next page

Table 7 continued

Pricing Scenarios (Cumulative Through 2050 Relative to the No Action Scenario)						
Scenario	**Sector**	**Description**	**Cumulative Potential GHG Emission Reductions** (tCO_2e)	**Percent Change by 2050 Relative to No Action Scenario** (%)	**Discounted Reduction Cost per Ton** (2010 KZT/ tCO_2e)	**Discounted Reduction Cost per Ton** (2010 \$/tCO_2e)
Emissions Trading Scheme	Industry / Electricity Production	An emissions cap is imposed on all industry (including mining) and electricity production, in three phases (from ICAP (2015)): By 2013, emissions are capped at their 2010 levels; In 2014, emissions across are capped at 2012 levels. In 2015, emissions are capped at 1.5% below those observed in 2013; and By 2020, the industrial and energy sector's CO_2 emissions are reduced by 15% relative to their 1992 levels.	1,544,370,058	−7.1	638.7	4.3
Extended ETS	All sectors	Continuing where the ETS scenario leaves off, the market-clearing price for carbon is assumed to grow at 3% each year through 2050. In addition, beginning in 2020 a carbon tax is applied across the remainder of the economy not covered by the original ETS, reaching parity with the ETS price by 2030.	1,558,672,146	−7.2	11,904.8	80.8
OECD Fuel Prices	All sectors	Prices for major fuels equalize with current (2013) OECD averages by 2030. Based on IEA (2014a).	1,124,925,667	−5.2	3,090.1	21.0

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Table 7 continued

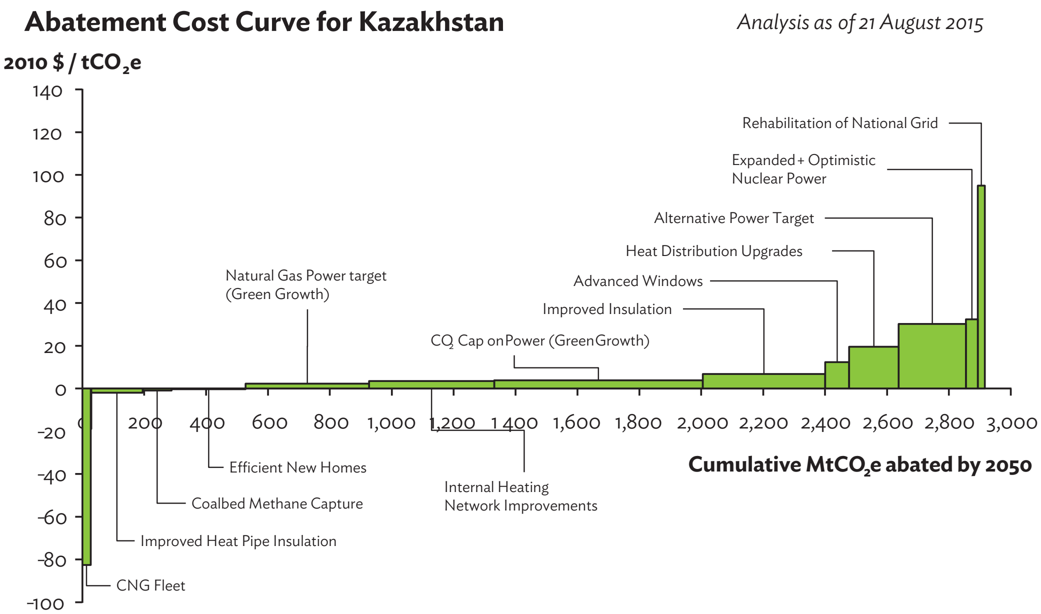
Combined Mitigation Scenarios (Cumulative Through 2050 Relative to the No Action Scenario)						
Scenario	**Sector**	**Description**	**Cumulative Potential GHG Emission Reductions** (tCO_2e)	**Percent Change by 2050 Relative to No Action Scenario** (%)	**Discounted Reduction Cost per Ton** (2010 KZT/tCO_2e)	**Discounted Reduction Cost per Ton** (2010 \$/tCO_2e)
All Low-Cost Technical Measures	All sectors	A combined scenario including all technical miniscenarios whose cumulative discounted direct cost per ton of GHG reductions <= 10 2010 $.	2,777,194,623	–12.9	768.4	5.2
All Technical Measures	All Sectors	All technical miniscenarios with positive abatement potential are combined into a full mitigation scenario. Overlaps between specific measures are addressed individually, as needed.	2,916,074,370	–13.5	956.0	6.5

CO_2 = carbon dioxide, ETS = emission trading scheme, GHG = greenhouse gas, GW = gigawatt, ICAP = International Carbon Action Partnership, km = kilometer, KZT = Kazakhstan tenge, LED = light-emitting diode, MW = megawatt, OECD = Organisation for Economic Co-operation and Development, UNDP = United Nations Development Programme, US EPA = United States Environmental Protection Agency.

Note: * Miniscenarios marked "NA" have undefined abatement costs since they result in increased or unchanged emissions. In many cases (e.g., the Renewable Power Target scenario in Azerbaijan), this result is due to interactions with miniscenarios ranked higher in the retrospective systems order.

Source: ADB. 2015b. *Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: The Economics of Reducing Greenhouse Gas Emissions in the Energy and Transport Sectors.* Consultant's report. Manila (TA 8119-REG).

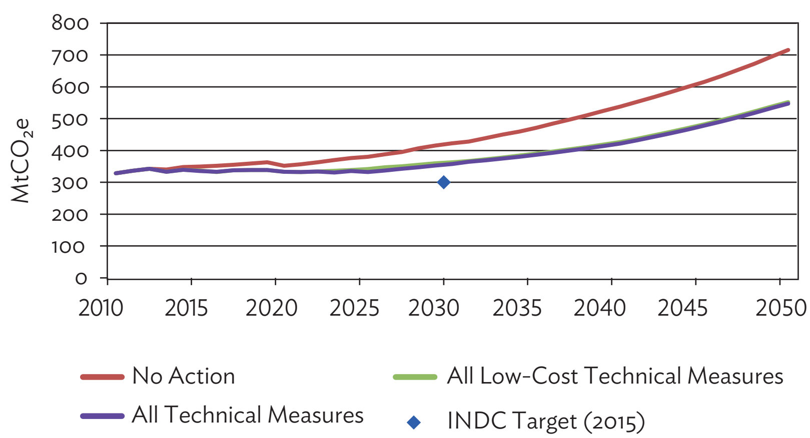
Figure 11: Marginal Abatement Cost Curve of Technical Mitigation Miniscenarios in Kazakhstan



CNG = compressed natural gas, $MtCO_2e$ = million tons of carbon dioxide equivalent.

Source: ADB. 2015b. *Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: The Economics of Reducing Greenhouse Gas Emissions in the Energy and Transport Sectors*. Consultant's report. Manila (TA 8119-REG).

Figure 12: Impact of Mitigation Options on Greenhouse Gas Emissions in Kazakhstan



INDC = Intended Nationally Determined Contribution, $MtCO_2e$ = million tons of carbon dioxide equivalent.

Source: ADB. 2015b. *Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: The Economics of Reducing Greenhouse Gas Emissions in the Energy and Transport Sectors*. Consultant's report. Manila (TA 8119-REG).

Table 8: Energy Security and Human Health Cobenefits of Mitigation in Kazakhstan (Cumulative Impacts by 2050 Relative to the No Action Scenario)

	Energy Security							Human Health	
	Cumulative Avoided Mortalities	Monetized Value of Avoided Mortalities (percent change, %)		Carbon Intensity of GDP (percent change, %)		Renewable Energy Percentage in Primary Energy Supply (percent change, %)		Cumulative Avoided Mortalities	Monetized Value of Avoided Mortalities (2010 $)
Mitigation Option	2010–2050	2010–2050	2050	2020	2010–2050	2010–2050	2050	2010–2050	2010–2050
Technical Mitigation Miniscenarios									
CNG Fleet	470	−0.60	0.00	0.00	0.20	0.80	0.00	3	$1,193,106
CNG Passenger Cars	25	0.00	0.00	0.40	0.20	0.00	0.00	0.1	$22,090
Improved Heat Pipe Insulation	1,604	0.00	−1.00	0.40	−1.00	0.00	1.00	0	$0
Coalbed Methane Capture	122	0.00	0.00	0.40	0.20	−1.20	0.00	−2	−$342,419
Efficient New Homes	2,307	−1.20	−1.30	−1.00	−1.30	1.20	1.30	0	$0
Natural Gas Power Target (Green Growth)	1,508	0.10	−1.40	0.40	−4.50	−0.10	10.20	634	$163,597,636
Internal Heating Network Improvements	3,906	0.00	−2.50	0.40	−2.80	0.00	2.60	0	$0
CO_2 Cap on Power (Green Growth)	1,907	−0.20	−1.30	−4.00	−14.80	31.80	29.40	1,152	$626,721,937
Improved Insulation	3,992	0.00	−2.60	0.40	−2.90	0.00	2.70	0	$0
Advanced Windows	838	0.00	−0.50	0.40	−0.40	0.00	0.50	0	$0
Heat Distribution Upgrades	3,261	−0.70	−2.00	−0.50	−2.10	0.70	2.00	0	$0
Alternative Power Target	2,204	0.10	−3.50	0.40	−10.90	−0.10	397.80	278	$59,461,986
Expanded + Optimistic Nuclear Power[a]	136	0.10	0.10	0.40	−0.20	0.20	−0.10	362	$61,617,376

[a] For the purposes of this mitigation analysis, the Expanded Nuclear Power and Optimistic Nuclear Power miniscenarios are combined so that the total abatement cost is reflective of all proposed nuclear expansions.

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Table 8 continued

	Energy Security							Human Health	
	Cumulative Avoided Mortalities	Monetized Value of Avoided Mortalities (percent change, %)		Carbon Intensity of GDP (percent change, %)		Renewable Energy Percentage in Primary Energy Supply (percent change, %)		Cumulative Avoided Mortalities	Monetized Value of Avoided Mortalities (2010 $)
Mitigation Option	**2010–2050**	**2010–2050**	**2050**	**2020**	**2010–2050**	**2010–2050**	**2050**	**2010–2050**	**2010–2050**
Rehabilitation of National Grid	302	0.00	0.20	0.40	−0.40	0.50	0.20	884	$174,150,546
Urban LED Lighting	366	0.10	−0.30	0.40	−0.20	−0.80	0.30	−4	−$1,261,905
Waste to Energy	14	0.10	0.00	0.40	0.20	−0.10	0.00	−0.3	−$71,473
Euro-5 Vehicles	−35	0.10	0.10	0.40	0.20	0.30	4.60	−6	−$927,279
Early Vehicle Retirement	−149	0.00	0.10	0.40	0.30	0.00	−0.10	−2	−$245,411
Pricing and Combined Mitigation Scenarios									
Emissions Trading Scheme	3,675	−6.10	0.00	−13.40	−2.60	37.40	5.90	5,582	$1,647,191,287
Extended ETS	2,320	−5.70	0.90	−14.90	−1.50	36.90	17.00	5,826	$1,692,388,280
OECD Fuel Prices	15,584	−3.90	−12.40	−1.20	−11.10	9.20	−1.10	283	$3,094,576
All Low-Cost Technical Measures	14,289	−3.09	−6.81	−4.96	−24.77	49.20	55.59	2,070	$550,556,144
All Technical Measures	16,945	−2.59	−7.72	−4.86	−25.49	40.65	68.60	3,109	$880,484,954

CNG = compressed natural gas, CO_2 = carbon dioxide, GDP = gross domestic product, LED = light-emitting diode, OECD = Organisation for Economic Co-operation and Development.
Note: Costs are discounted using a 7% real discount rate.
Source: ADB. 2015b. *Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: The Economics of Reducing Greenhouse Gas Emissions in the Energy and Transport Sectors.* Consultant's report. Manila (TA 8119-REG).

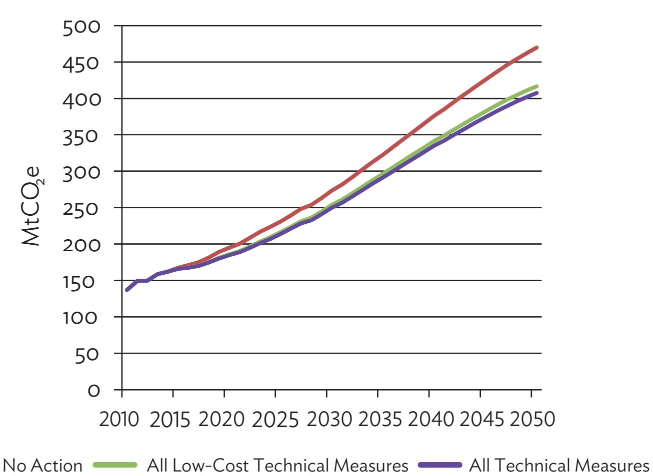
The mitigation measures based on improved heat pipe insulation, efficient new homes, the natural gas power target, the CO_2 cap on power, internal heating network improvements, improved insulation, heating distribution upgrades, and the alternative power target in Kazakhstan result in significant fuel savings. Similar to the results for Azerbaijan, pricing scenarios were particularly effective in reducing GHG emissions in Kazakhstan. For instance, the OECD fuel price scenario results in savings of 15,584 gigajoules, which is almost as much as all of the technic al mitigation measures combined. This indicates that the mitigation measures proposed by the Government of Kazakhstan are already designed to have a significant impact on energy consumption.

Costs and Benefits of Abatement Options in Uzbekistan

Direct Costs of Abatement and Corresponding Greenhouse Gas Reductions

The set of technical mitigation options for Uzbekistan results in about 10% abatement in comparison to the No Action Scenario (Figure 13). Most of the mitigation potential is low cost or result in overall savings to the country; for example, implementing all the low-cost technical measures analyzed for Uzbekistan can be done at a discounted cost of -\$33 per tCO_2e (see Table 9). Adding the higher cost options that were analyzed provides only modest abatement gains (Figure 14).

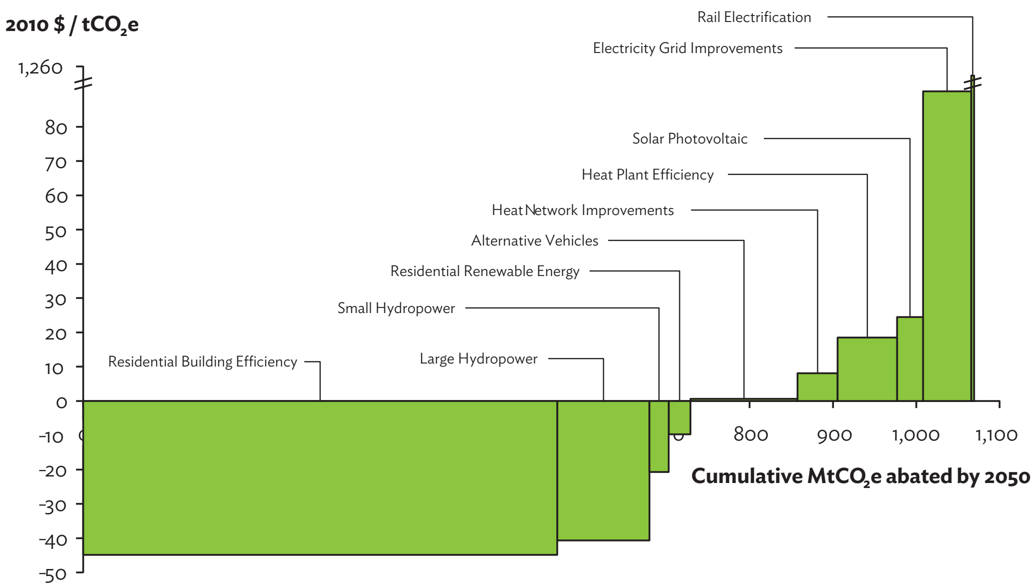
Figure 13: Impact of Mitigation Options on Greenhouse Gas Emissions in Uzbekistan



$MtCO_2e$ = million tons of carbon dioxide equivalent.

Source: ADB. 2015b. *Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: The Economics of Reducing Greenhouse Gas Emissions in the Energy and Transport Sectors*. Consultant's report. Manila (TA 8119-REG).

Figure 14: Marginal Abatement Cost Curve of Technical Mitigation Miniscenarios in Uzbekistan



$MtCO_2e$ = million tons of carbon dioxide equivalent.

Source: ADB. 2015b. *Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: The Economics of Reducing Greenhouse Gas Emissions in the Energy and Transport Sectors*. Consultant's report. Manila (TA 8119-REG).

The Residential Building Efficiency scenario assumes a decrease in specific energy consumption in residences—about 80% between now and 2050. Coupled with projected growth in residential building space (from around 450 million square meters [m^2] in 2012 to 965 million m^2 in 2050 in all scenarios), this change produces energy and emissions savings.[15] The total cumulative abatement potential by 2050, 569 $MtCO_2e$, is the largest provided by any of the individual mitigation measures assessed here for Uzbekistan, and at a negative cumulative cost per ton of abatement (Table 9). Increased renewable energy capacities in the country, through the scenarios of Large and Small Hydro as well as Residential Renewable Energy, also represent a cost-effective approach to GHG mitigation, although hydropower may include potential indirect costs, such as ecosystem damages and impacts on rural livelihoods, which must be weighed against the GHG benefits of hydropower and considered in decision-making.

In Uzbekistan, the energy efficiency and renewable energy measures analyzed result in significant emission reductions by 2050. However, these reductions are offset by the rapid economic and energy demand growth assumed in the No Action Scenario and emissions continue to rise.

Indirect Cobenefits of Greenhouse Gas Mitigation

In Uzbekistan, all the measures analyzed result in measurable fuel savings, with residential building efficiency potentially contributing two-thirds of the potential savings. The results for

[15] ADB. 2015b. *Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: The Economics of Reducing Greenhouse Gas Emissions in the Energy and Transport Sectors*. Consultant's report. Manila (TA 8119-REG).

Table 9: Direct Costs and Abatement Potential for Mitigation Scenarios in Uzbekistan

Technical Mitigation Miniscenarios (Cumulative through 2050 Using Retrospective Systems Analysis)					
Scenario	Sector	Description	Cumulative Potential GHG Emission Reductions (tCO_2e)	Discounted Reduction Cost per Ton (2013 UZS/ tCO_2e)	Discounted Reduction Cost per Ton (2010 \$/ tCO_2e)
Residential Building Efficiency	Residential	Reductions in residential building-specific energy consumption (total energy demand/m^2 floor space) due to enhanced efficiency standards for new buildings and retrofits of existing buildings. Average specific energy consumption falls to 250 kWh/m^2/year by 2030 and 70 kWh/m^2/year by 2050. Based on UNDP (2015).	569,147,765	–111,064.7	–44.9
Large Hydropower	Electricity Production	Large hydropower component of the State Program on Development of Hydropower: 1,824 MW capacity expansion of large hydropower by 2030. New capacity is in addition to that constructed in No Action Scenario.	110,835,506	–100,493.5	–40.7
Small Hydropower	Electricity Production	Small hydropower component of the State Program on Development of Hydropower: 688.5 MW capacity expansion of small hydro by 2030. New capacity is in addition to that constructed in No Action Scenario.	22,924,927	–51,184.7	–20.7
Residential Renewable Energy	Residential	Deployment of solar PV, solar hot water, and biogas for residential buildings, collectively accounting for 1% of residential energy demand by 2030 and 5% by 2050. Based on UNDP (2015).	26,166,554	–24,043.9	–9.7
Alternative Vehicles	Transport	A scenario in which 29% of 1.634 million vehicles currently on the road switch from gasoline or diesel to compressed natural gas, by the year 2016. Described in Azernews (2013).	128,471,751	1,546.2	0.6
Heat Network Improvements	Heat Production	Reductions in heat transmission and distribution losses due to heating network improvements. Total losses reach 20% by 2030 and 10% by 2050. Based on UNDP (2015).	48,112,419	19,898.4	8.1
Heat Plant Efficiency	Heat Production	An accelerated increase (compared to the No Action Scenario) in the efficiency of natural gas-powered heat plants. Average efficiency reaches 80% by 2030 and 90% by 2050. Based on UNDP (2015).	71,424,254	45,803.2	18.5
Solar Electricity	Electricity Production	Construction of approximately 1,650 MW solar PV capacity and 330 MW concentrated solar power capacity by 2030. Based on the “Optimistic” development trajectory described in STA et al. (2014b; 2015a).	31,200,307	60,451.5	24.5

continued on next page

Table 9 continued

Technical Mitigation Miniscenarios (Cumulative through 2050 Using Retrospective Systems Analysis)					
Scenario	**Sector**	**Description**	**Cumulative Potential GHG Emission Reductions (tCO_2e)**	**Discounted Reduction Cost per Ton (2013 UZS/ tCO_2e)**	**Discounted Reduction Cost per Ton (2010 $/ tCO_2e)**
Electricity Grid Improvements	Electricity Production	Reductions in electricity transmission and distribution losses due to grid improvements. Total losses reach 15% by 2030 and 10% by 2050. Based on UNDP (2015).	57,640,715	223,258.6	90.3
Rail Electrification	Transport	45% of railways are electrified by 2030, and the percentage remains constant through 2050. Based on Center for Economic Research and UNDP (2014).	3,737,049	3,107,406.1	1,257.3

Combined Mitigation Scenarios (Cumulative Through 2050 Relative to the No Action Scenario)						
Scenario	**Sector**	**Description**	**Cumulative Potential GHG Emission Reductions (tCO_2e)**	**Percent Change by 2050 Relative to No Action Scenario (%)**	**Discounted Reduction Cost per Ton (2013 UZS/ tCO_2e)**	**Discounted Reduction Cost per Ton (2010 $/$tCO_2e$)**
All Low-Cost Technical Measures	All sectors	A combined scenario including all technical miniscenarios whose cumulative discounted direct cost per ton of GHG reductions <= 10 2010 $.	905,658,923	–6.5	–82,809.3	–33.5
All Miniscenarios	All sectors	All technical miniscenarios with positive abatement potential are combined into a full mitigation scenario. Overlaps between specific measures are addressed individually, as needed.	1,069,661,249	–7.7	–42,404.2	–17.2

GHG = greenhouse gas, kWh = kilowatt hour, m^2 = square meter, MW = megawatt, PV = photovoltaic, tCO_2e = ton of carbon dioxide equivalent, UNDP = United Nations Development Programme, UZS = Uzbekistan som.

Notes: * Miniscenarios marked "NA" have undefined abatement costs since they result in increased or unchanged emissions. In many cases (e.g., the Renewable Power Target scenario in Azerbaijan), this result is due to interactions with miniscenarios ranked higher in the retrospective systems order.

Source: ADB. 2015b. *Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: The Economics of Reducing Greenhouse Gas Emissions in the Energy and Transport Sectors.* Consultant's report. Manila (TA 8119-REG).

Table 10: Energy Security and Human Health Cobenefits of Mitigation in Uzbekistan (Cumulative Impacts by 2050 Relative to the No Action Scenario)

	Energy Security							Human Health	
	Cumulative Avoided Mortalities	Monetized Value of Avoided Mortalities (percent change, %)		Carbon Intensity of GDP (percent change, %)		Renewable Energy Percentage in Primary Energy Supply (percent change, %)		Cumulative Avoided Mortalities	Monetized Value of Avoided Mortalities (2010 $)
Mitigation Option	2010–2050	2010–2050	2050	2020	2010–2050	2010–2050	2050	2010–2050	2010–2050
Technical Mitigation Miniscenarios									
Residential Building Efficiency	9,686	−3.69	−8.90	−3.87	−9.37	3.07	7.19	39	$2,993,208
Large Hydropower	898	−0.47	−0.47	−1.04	−1.02	24.38	24.49	155	$10,879,816
Small Hydropower	181	−0.11	−0.08	−0.24	−0.20	5.46	5.81	25	$1,781,548
Residential Renewable Energy	846	−0.18	−0.85	−0.21	−0.83	−0.07	−1.80	26	$1,475,678
Alternative Vehicles	1,882	−0.60	−1.87	−0.71	−2.29	0.62	1.97	146	$6,370,534
Heat Network Improvements	776	−0.05	−1.05	−0.06	−1.17	0.05	1.06	0	$0
Heat Plant Efficiency	1,206	−0.21	−1.17	−0.23	−1.30	0.21	1.19	0	$0
Solar Photovoltaic	270	−0.13	−0.16	−0.28	−0.34	6.71	8.41	43	$2,829,712
Electricity Grid Improvements	1,085	−0.31	−0.97	−0.37	−0.94	−0.28	−3.53	52	$3,239,945
Rail Electrification	22	0.00	−0.01	0.00	−0.03	0.04	0.19	22	$862,994
Combined Mitigation Scenarios									
All Low-Cost Measures	13,875	−5.03	−12.66	−5.98	−14.34	34.52	44.54	379	$22,768,063
All Technical Measures	16,350	−5.64	−14.85	−6.77	−16.83	40.83	53.00	489	$29,319,380

GDP = gross domestic product.

Source: ADB. 2015b. *Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: The Economics of Reducing Greenhouse Gas Emissions in the Energy and Transport Sectors.* Consultant's report. Manila (TA 8119-REG).

Uzbekistan indicate that the largest cobenefit effects arise from the All Miniscenarios option, which shows 489 avoided mortalities and improvements in energy security, particularly with respect to the share of renewable energy in total energy supply. Among the individual mitigation options, the Large Hydropower and Alternative Vehicle options produce the most significant cobenefits. Both of these options have similar health effects (about 150 avoided mortalities), but Large Hydropower has larger benefits for energy security. None of the mitigation options for Uzbekistan result in increases in air pollutant-related mortalities.

Nationally Appropriate Mitigation Actions and Investment Concept Notes in the Region

The first mention of NAMAs appeared in the 2007 Bali Action Plan as "nationally appropriate mitigation actions by developing country Parties in the context of sustainable development, supported and enabled by technology, financing and capacity building, in a measurable, reportable and verifiable manner."[16] The 2010 Cancun Decision later clarified the term, specifying that NAMAs must

(i) take place within a context of sustainable development;
(ii) be supported and enabled by technology transfer, financing, and capacity building;
(iii) contribute to reducing emissions relative to business-as-usual in 2020; and
(iv) result in greenhouse gas (GHG) emission reductions that are measured, reported, and verified.[17]

NAMAs must be the product of a national government initiative and may take the form of policies directed at transformational change within an economic sector or actions across sectors for a broader national focus.[18] They are voluntary and do not represent a legal obligation under the United Nations Framework Convention on Climate Change. NAMAs must support sustainable development and fit within a country's national development priorities. Within this context, they can take different forms: sector plans; specific policies, regulations, and programs; or individual projects.

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[16] UNFCCC. 2007. *Report of the Conference of the Parties on its thirteenth session, held in Bali from 3 to 15 December 2007.* Addendum. Part Two: Action taken by the Conference of the Parties at its thirteenth session. FCCC/CP/2007/6/Add.1*. March 14 2008. Bonn. http://unfccc.int/resource/docs/2007/cop13/eng/06a01.pdf

[17] UNFCCC. 2010. *The Cancun Agreements: Outcome of the work of the Ad Hoc Working Group on Further Commitments for Annex I Parties under the Kyoto Protocol at its fifteenth session.* Decision 1/CMP.6. Bonn. Accessed at: http://unfccc.int/resource/docs/2010/cmp6/eng/12a01.pdf

[18] UNFCCC. *FOCUS: Mitigation – NAMAs, Nationally Appropriate Mitigation Actions.* http://unfccc.int/focus/mitigation/items/7172.php

Box 2: Transformational Change in the Context of Nationally Appropriate Mitigation Actions, as Defined by the NAMA Facility

To obtain financial or technical support for implementation of a NAMA, a proponent must demonstrate that the proposed concept:

- contributes to enabling either a significant evolution in scope (e.g., scaling-up or replication) or a faster shift from one state to another;
- has a catalytic effect and includes (a) mechanisms to ensure the sustainability of the impacts, local ownership, and political will; (b) the involvement of the private sector; and (c) the use of innovative technologies and approaches; and
- allows for systematic learning processes.

Source: The NAMA Facility. 2014. *Potential for Transformational Change*. Accessed at: http://www.nama-facility.org

Work on NAMAs is still in the early stages in Azerbaijan, Kazakhstan, and Uzbekistan, and the formal institutional framework supporting NAMA development and implementation is in its early stages. As part of this technical assistance (TA) project, a NAMA was developed for each country, designed to be general concept notes that can be modified by potential funders based on their specific guidelines. Each of these is presented in Table 11.

The NAMAs were developed in consultation with government counterparts in each country and were formulated as stand-alone write-ups for each government to use for its own needs. The selection of the NAMAs grew out of consultations conducted during workshops and individual meetings with stakeholders in each country. Beyond their contributions to avoiding GHG emissions, the NAMAs were selected based on their alignment with national development priorities and the commitment and willingness of individual stakeholder agencies to engage in the NAMA process. The mitigation options selected for NAMAs were found to have no or very little cost per ton of carbon dioxide equivalent (tCO_2e) abated and are therefore attractive from the perspective of social benefits. The NAMA to foster use of natural gas for transport in Kazakhstan (-82.6 $\$/tCO_2e$) and the NAMA to accelerate small-scale hydropower in Uzbekistan (-20.7 $\$/tCO_2e$) both result in cost savings to society. The NAMA to promote agro-energy development based on renewable energy in Azerbaijan is low cost (10 $\$/tCO_2e$) and results in important energy security and rural development benefits.

In recognition that early investment into the NAMA may help increase the success of the overall policy framework, the identification and formulation of three climate change investment concepts in support of the NAMA concepts were carried out for each of the countries. These include the construction of solar photovoltaic and biogas plants at the Samukh Agro-Energy Residential Complex in Azerbaijan, construction of a network of 10 compressed natural gas (CNG) refueling stations in Kazakhstan, and construction of the Tuyabuguzskaya Small Hydropower Plant in Uzbekistan. These concept notes focus mostly on investment in hard components, such as specific renewable energy projects in Azerbaijan and Uzbekistan, and CNG refueling infrastructure in Kazakhstan. These elements include workshops to provide technical training on how to convert existing vehicles to CNG, creation of testing and certification centers, and introduction of training facilities for technicians who can convert and maintain the vehicles.

Table 11: Proposed Nationally Appropriate Mitigation Action Concepts for Azerbaijan, Kazakhstan, and Uzbekistan

Country	Azerbaijan	Kazakhstan	Uzbekistan
NAMA	Promoting Agro-Energy Development Based on Renewable Energy	Fostering Use of Natural Gas in the Transport Sector	Accelerating Deployment of Small-Scale Hydropower
Description[a]	Supports construction of renewable energy at agricultural complexes throughout Azerbaijan, revises the normative and regulatory framework for renewable energy, and pilots the concept at the Samukh agro-energy complex.	Expands the CNG refueling infrastructure, converts vehicles to natural gas, and increases the technical capacity to support CNG in transport.	Addresses institutional and investment barriers to the acceleration of small-scale hydropower and finances the rehabilitation of existing plants and construction of new small hydropower plants.
Potential GHG Emission Reductions (tCO_2e)[a]	116,825–584,125 annually by 2020	135,315–1,766,574 annually by 2025	918,715 annually by 2030
Time Period[a]	2014–2020	2014–2025	2015–2030
Cost of implementation (Million $)[a]	278	74	729
Average Cost of GHG Abatement[b] (2010 $/$tCO_2e$)	10	-83	-21

CNG = compressed natural gas, GHG = greenhouse gas, tCO_2e = tons of carbon dioxide equivalent.

Sources:

[a] ADB. 2015c. *Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: Report on Nationally Appropriate Mitigation Actions*. Consultant's report. Manila (TA 8119-REG).

[b] ADB. 2015a. *Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: Final Summary Report and Investment Concept Notes*. Consultant's report. Manila (TA 8119-REG).

Table 12: Investment Concept Notes for Azerbaijan, Kazakhstan, and Uzbekistan

Country	Azerbaijan	Kazakhstan	Uzbekistan
Investment Concept	**Construction of solar photovoltaic (PV) and biogas plants at the Samukh Agro-Energy Residential Complex**	**Construction of a network of 10 compressed natural gas (CNG) refueling stations**	**Construction of the Tuyabuguzskaya Small Hydropwer Plant (SHP)**
Sector	Energy	Transport	Energy
Description	• Construct a 3.2 MW solar PV plant • Construct a 0.75 MW electricity and 0.75 MW heat biogas plant	• Construct 10 CNG refueling stations • Technical training on how to convert vehicles • Build training facilities for vehicle technicians • Create testing and certification centers	• Construct 2 x 6.25 MW units at the Tuyabuguzskaya SHP below an existing irrigation dam
Time Period	2015–2045	2015–2030	2015–2030
Total funding ($ Million)	16	25	20
International Funding Share	10–13	12–16	17
IRR (%)	11–15	13–30	12
NPV ($)	550,300–1,550,000	594,656–3,307,706	675,000
Simple Payback Period (Years)	16	3–9	13
GHG Emission Reductions (tCO_2e)	To be determined based on ongoing feasibility study	This investment does not result in direct emissions reductions. Indirectly it supports implementation of the NAMA which will result in reductions of 135,315 to 1,766,574 annually by 2025	22,238 annually

GHG = greenhouse gas, IRR = internal rate of return, MW = megawatt, NAMA = nationally appropriate mitigation action, NPV = net present value, tCO_2e = ton of carbon dioxide equivalent.

Source: ADB. 2015a. *Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: Final Summary Report and Investment Concept Notes*. Consultant's report. Manila (TA 8119-REG).

Nationally Appropriate Mitigation Actions and Investment Concept Notes for Azerbaijan

Nationally Appropriate Mitigation Action Institutions

The government of Azerbaijan supports nationally appropriate mitigation action (NAMA) initiatives in the context of the United Nations Framework Convention on Climate Change (UNFCCC) negotiating process. The Ministry of Ecology and Natural Resources (MENR) leads and coordinates Azerbaijan's NAMA process and represents the country during UNFCCC negotiations. As the UNFCCC National Focal Point for Azerbaijan, the MENR also approves and submits NAMA ideas to the UNFCCC NAMA Registry. Azerbaijan included an update on NAMAs in the country's first biennial update report, submitted to the UNFCCC in March 2015.

Azerbaijan has expressed interest in reaching a new global agreement that takes into account climate change adaptation, technology transfer, finance, and capacity building issues, along with support for climate change mitigation. To that end, Azerbaijan launched an internal government process and stakeholder consultations, led by the MENR, to prepare the Intended Nationally Determined Contribution (INDC). In May 2014, the Cabinet of Ministers assigned all relevant ministries to prepare INDC proposals; the ministries submitted their proposals to the MENR in late 2014. The government finalized its INDC in August 2015 and has submitted it to the UNFCCC Secretariat. In its INDC, Azerbaijan committed to a 35% reduction of total greenhouse gas (GHG) emissions compared to the 1990 base level by 2030, through a combination of mitigation measures in the following sectors:[19]

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[19] Government of Azerbaijan. 2015. *Intended Nationally Determined Contribution.* http://www4.unfccc.int/submissions/INDC/Published%20Documents/Azerbaijan/1/INDC%20Azerbaijan.pdf

- Energy sector (e.g., implementation of legislative regulations, energy efficiency measures, replacement with modern electricity generation technologies, reconstruction of distribution networks and distribution lines, increased use or alternative and renewable energy sources).
- Oil and gas sector (e.g., application of modern processing technologies in line with Euro-5 standards, modernization of gas pipelines to reduce fugitive losses).
- Residential and commercial sectors (e.g., widespread use of control and measurement devices in electrical, heat energy, and natural gas systems; application of energy-efficient bulbs).
- Transport sector (e.g., enhancement of use of electric vehicles, rail electrification, development of infrastructure for mass transportation).
- Agriculture sector (e.g., collection of methane gas from manure of livestock and poultry, and use of alternative sources of energy and modern technologies).
- Waste sector (e.g., development of modern solid waste management system in big cities of the country).
- Land use, land use change, and forestry sector (e.g., reforestation or afforestation, establishment of forested buffer zones, and improved management of pastures and agricultural lands).

During the inception workshops for the technical assistance (TA) project that financed this study, stakeholders in Azerbaijan identified several barriers to NAMA development, including the following:[20]

(i) There is no coordinating body within the government to facilitate collaboration on NAMAs across agencies. The MENR is the contact point for NAMAs developed by other agencies and approves submissions to the UNFCCC NAMA Registry, but it does not have a mandate to develop or spearhead efforts to prepare NAMAs for submission on behalf of other agencies. The MENR therefore depends on champions in other parts of the government to conceive of potential NAMAs and encourage collaboration to address potential interagency barriers to implementation;

(ii) Relevant national stakeholders' current knowledge and capacity to develop NAMAs is low, particularly among government representatives. In the past, participants in related international capacity building activities were largely composed of representatives from nongovernment organizations; and

(iii) Azerbaijan's private sector has been reluctant to engage in NAMAs, mainly because of negative experiences with projects under the Clean Development Mechanism. Without private sector participation in financing, however, the government would have to act as the key investor. This could potentially limit the share of investment covered by national contributions.

[20] Abt Associates. 2014. *Workshop Summary: National Inception Workshop for Azerbaijan.* Baku. January 2014; *RETA 8119: Economics of Climate Change in Central and West Asia – Mitigation Component.* Washington, DC: Abt Associates; Abt Associates. 2014. *Workshop Summary: Regional Inception Workshop – Developing Climate Change Mitigation Policies and Nationally Appropriate Mitigation Actions (NAMAs).* Baku. January 2014.

Existing Nationally Appropriate Mitigation Action Proposals

To date, stakeholders in Azerbaijan have developed two NAMA proposals:

1. NAMA for Low-Carbon End-Use Sectors in Azerbaijan—to support the State Oil Company of the Azerbaijan Republic (SOCAR) in developing and implementing selected programmatic NAMAs in low-carbon end-use sectors.[21]
2. NAMA for the Foam, Refrigeration, and Air-Conditioning Sectors—to reduce GHG emissions by introducing environmentally friendly and energy-efficient technologies; this is expected to avoid direct emissions from refrigerants and blowing agents and indirect emissions that stem from energy consumption by old, inefficient equipment.

Several other NAMA ideas are in the early preparation stages.

Background and Rationale

In 2010, fossil fuels met 98.8% of Azerbaijan's primary energy supply. Since then, several new renewable energy facilities have come online; although less than 25% of the country's electricity generation capacity is from renewables. All of the country's heat capacity is powered by fossil fuels. Meanwhile, Azerbaijan has significant potential for renewable energy, particularly wind and solar (Table 13).

Table 13: Potential Renewable Resource Yields in Azerbaijan

Resource	Annual Yield
Biomass	0.77 billion kWh
Large Hydropower	11 billion kWh
Small Hydropower	5 billion kWh
Solar	39.6 billion kWh
Wind	86.4 billion kWh
Total Primary Energy Supply (TPES) in 2010	135.9 billion kWh

kWh = kilowatt hour.

Source: Government of Azerbaijan, Ministry of Ecology and Natural Resources. 2012. Technology Needs Assessment—Mitigation. http://www.tech-action.org/Participating-Countries/Phase-1-Asia-and-CIS/Azerbaijan

The government is working to diversify Azerbaijan's economy and stimulate production in the non-oil sectors. This includes increased investment in renewable energy, regional development, and high-technology production in agriculture. The government of Azerbaijan has adopted several strategies and goals to promote renewable energy. The State Program on Utilization of Renewable and Alternative Sources of Energy (2008–2015) set a target of 20% for non-fossil-fuel-based energy by 2020. In support of this program, the government established the State Agency on Alternative and Renewable Energy Sources (SAARES). In 2011, the President issued a new order setting a target for alternative and renewable energy for 2020, 9.7% of total energy

[21] UNDP. 2013. *Nationally Appropriate Mitigation Actions for low-carbon end-use sectors in Azerbaijan: Background.* Azerbaijan. Accessed at: http://www.az.undp.org/content/azerbaijan/en/home/operations/projects/sustain_development/NAMA.html

and 20% of electricity consumption, as well as a target of 2,000 megawatts (MW) of renewable energy capacity installed.[22] SAARES was directed to develop a strategy to meet this target.

In December 2014, SAARES released its strategic plan for 2015–2018 which lays out its strategy for increasing renewable energy capacity. The plan includes measures such as modifying existing norms and regulations to incentivize renewable energy development by the private sector, offering preferential loans, increasing technical capacity, removing import duties on renewable energy equipment, improving institutional arrangements to support tracking and evaluation of renewable energy, and conducting education and outreach. According to the strategic plan, SAARES will construct 187 MW wind, 369 MW solar, 63 MW bioenergy, and 116 MW hydropower capacity from 2015 to 2018. Altogether, the plan will result in 735 MW of new alternative and renewable energy.[23] To further the implementation of renewable energy, SAARES is studying and developing a new tariff methodology for renewable and alternative energy, and a new tariff will be set for solar power by the end of 2015.

Proposed Nationally Appropriate Mitigation Action: Promoting Agro-Energy Development Based on Renewable Energy

In support of the government of Azerbaijan's goal to increase the use of renewable energy, ADB partnered with SAARES to develop a concept for a NAMA that accelerates the adoption of renewable energy in the agricultural sector. The NAMA, entitled "Promoting agro-energy development based on renewable energy in Azerbaijan," is expected to support construction of renewable energy plants in agricultural complexes in Azerbaijan, revise the normative and regulatory framework for renewable energy, and pilot the concept at the Samukh agro-energy complex. The Azerbaijan SAARES will lead the NAMA's design and implementation. SAARES is a government agency established in 2010 to implement state policy on renewable energy, develop the infrastructure for renewable energy, oversee the adoption of renewable energy in all sectors of the economy, and track and report on renewable energy activities. To fulfill this mandate, SAARES proposed to develop a NAMA to pilot several renewable energy technologies in an agricultural complex that would promote rural employment and economic development. By combining the piloting of renewable technologies with normative and legal reforms for tariffs, import duties, and credit for renewables, Azerbaijan hopes to facilitate increased investment in renewables for agriculture and other sectors.

When SAARES commissioned and initiated construction of the Samukh Agro-Energy Residential Complex, it set out to increase the use of renewable energy, test innovative development in an agriculture-centered region, improve the reliability of the electricity supply, and meet the Samukh district's growing demand for electricity and heat. The Samukh complex's long-term goal is to provide a proof-of-concept for other hybrid facilities that will help Azerbaijan move toward more modern, highly efficient, low-emission, and waste-free rural development. Using the lessons learned from Samukh, SAARES plans to replicate the complex at five other sites in

[22] Government of Azerbaijan. 2011. *Order of the President of Republic of Azerbaijan on Preparation of a National Strategy on the Use of Alternative and Renewable Energy Sources for 2010–2020.*

[23] Government of Azerbaijan, State Agency for Alternative and Renewable Energy Sources. 2014. *Strategic Plan (2015-2018).* http://area.gov.az/strateji-plan-2015-2018/

Azerbaijan: Balaka, Gadabav, Nakhchivan, Neftchala, and Oghuz. These sites were identified for potential expansion because of unmet energy demand, expected population growth, and favorable renewable energy resource mapping.

To help improve conditions for replicability and ensure sustainability upon completion of the Samukh complex, SAARES will introduce supporting measures for advancing renewable energy, including

(i) a program to provide preferential loans for alternative and renewable energy sources;
(ii) customs duty exemptions for equipment, spare parts, and other devices for renewable and alternative energy production; and
(iii) proposed electricity tariffs designed for alternative and renewable energy sources.[24]

The construction of renewable energy capacity at Samukh and other agro-energy complexes in Azerbaijan will avert GHG emissions by displacing electricity or heat that would otherwise be generated predominantly by fossil fuel.

Greenhouse Gas Emissions Reductions

The NAMA's renewable energy capacity will replace the consumption of electricity from the grid, which is powered mostly by fossil fuels. It will also provide heat, which in Azerbaijan is generated 100% by fossil fuel. The fuel switch will result in reductions of three GHGs: carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). The GHG impact of the renewable energy NAMA will depend on the success of the Samukh complex and on the technical feasibility of installing renewable energy capacity at the other sites. It will also depend on the specific changes to be made to the normative and regulatory framework governing renewable energy in general.

Without the NAMA, the agricultural output projected for the Samukh complex and the other five planned agricultural complexes would likely be produced by traditional farms located elsewhere in Azerbaijan. Because these traditional farms depend on electricity from the national grid and use fossil fuels for heat generation, the assumption for the baseline (without the NAMA) is that the existing fuel mix would produce the required electricity and heat.

Using the Long-Range Energy Alternative Planning (LEAP) economic model the annual GHG emissions for electricity and heat generation with and without the NAMA were estimated for the period 2015–2020 (Table 14), which describes the annual expected GHG emission reductions from the renewable energy capacity to be installed at the Samukh Agro-Energy Residential Complex.

If the Samukh Agro-Energy Residential Complex succeeds and is replicated at other sites in Azerbaijan, and assuming that the complexes are similar in size to Samukh, the potential *additional* emission reductions are roughly estimated by multiplying year 2020 GHG emission reductions by 5. That is, additional GHG emission reductions would eventually be 116,825 tCO_2e/year * 5 =

[24] Government of Azerbaijan, State Agency for Alternative and Renewable Energy Sources. 2014. *Strategic Plan (2015–2018)*. http://area.gov.az/strateji-plan-2015-2018/

Table 14: Annual Greenhouse Gas Emissions from Electricity and Heat Generation in Azerbaijan with and without the Nationally Appropriate Mitigation Action, 2015–2020

	Phase 1		Phase 2			
Year	2015	2016	2017	2018	2019	2020
Baseline without the NAMA						
GHG emissions from electricity and heat generation in Azerbaijan (tCO_2e)	13,933,833	13,847,079	13,799,211	13,820,095	13,885,779	13,862,349
Average emission factor for the grid (tCO_2e/MWh)	0.429	0.428	0.429	0.429	0.429	0.429
With the NAMA						
GHG emission reductions from introducing the NAMA (tCO_2e)	9,053	–18,560	–42,645	–66,789	–92,232	–116,825
% Change from baseline	–0.06	–0.13	–0.31	–0.48	–0.66	–0.84

GHG = greenhouse gas, MWh = megawatt hour, NAMA = nationally appropriate mitigation action, tCO_2e = ton of carbon dioxide equivalent.

Source: ADB. 2015b. *Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: The Economics of Reducing Greenhouse Gas Emissions in the Energy and Transport Sectors*. Consultant's report. Manila (TA 8119-REG).

584,125 tCO_2e/year, which equals 4.21% of 2020 baseline GHG emissions from electricity and heat generation in Azerbaijan. However, this number is highly uncertain, as it depends on the actual renewable energy capacity to be installed at each site.

Cobenefits of the Proposed Nationally Appropriate Mitigation Action

In addition to averting GHG emissions, the cobenefits of the Samukh Agro-Energy Residential Complex are numerous. In many rural areas, the lack of dependable, uninterrupted, and affordable sources of electricity and heat poses a major barrier to the implementation of modern agricultural techniques and state-of-the-art food processing technologies.

The main outcomes of the Samukh complex are expected to include:

(i) increased agricultural production in the region, providing food and other agricultural products to the residents of Samukh and the city of Ganja;
(ii) sustainable generation of renewable energy and experience gained in building and managing a diverse renewable energy system;
(iii) increased public awareness of the comprehensive approach to agricultural planning and development, which is based on the latest agro-technologies, provides high-quality organic products, and incorporates an environment-friendly, waste-free or waste-to-energy philosophy; and
(iv) creation of new jobs in a region where job creation is slowing. According to the State Statistical Committee, 1,067 new permanent jobs were created in 2005 versus 308

permanent jobs in 2013, indicating a slower rate of job creation compared to other parts of the country.[25]

Barriers That Would Be Addressed by the Nationally Appropriate Mitigation Action

Construction of the Samukh Agro-Energy Residential Complex will help address several barriers to the adoption of renewable energy. Key barriers include the following:

(i) **Financial and economic barriers.** The high cost of the equipment needed for reliance on renewable energy sources, limited access to credit for the purchase and installation of such equipment, and unfavorable terms of financing even when credit is available all pose barriers to the adoption of renewable energy sources. Moreover, the tariff structure is insufficient to support solar, biogas, and geothermal sources. The special tariff of Azerbaijan manat (AZN)0.025 and AZN0.045 for small hydropower and wind sources is insufficient to recover costs for those technologies.[26]

(ii) **Policy barriers.** The absence of incentives for green investment, rather than a lack of or poorly formulated policies per se, poses a barrier to adoption. While the government recognizes and affirms the urgent need to expand generation of renewable energy, it has yet to advance policies to mandate the adoption of renewable energy. Therefore, renewable energy sponsors cannot count on any targeted incentives—soft loans, tax breaks, or custom duty waivers—except in the three technological parks established by presidential decree.

(iii) **Other barriers.** Other barriers relate to the scarcity of national experience with modern, highly efficient, and renewable energy-based technologies, especially in the agricultural and food processing sectors. Furthermore, traditional approaches to rural development often do not recognize the potential for alternative and climate-friendly growth strategies.

The renewable energy NAMA intends to tackle these barriers by

(i) leveraging targeted national and multilateral funding to catalyze investment in renewable energy technologies,
(ii) forming a renewable energy cluster that encourages experimentation with optimal use of local energy resources and creates domestic expertise with new technologies,
(iii) establishing a proving ground and training facilities for state-of-the-art agricultural technologies, and
(iv) raising awareness of a new low-emission comprehensive approach to rural development among the public and decision makers from the local to national levels.

Restructuring tariffs for renewables, providing preferential loans, and creating a tax exemption for imported equipment will help address the financial, economic, and policy barriers described

[25] Government of Azerbaijan, State Statistical Committee. 2015. *Samukh.* Environment and Other Indicators, the Regions. Baku. Accessed at: http://www.stat.gov.az/source/regions/az/004_7.xls

[26] UNFCCC. 2011. *Project Design Document.* Project 4822: Yeni Yashma Wind Farm. Azerbaijan. Bonn. http://cdm.unfccc.int/UserManagement/FileStorage/192AOK6HMSEWBVQX7PCNRFG4DZ0UJ3

above by improving the tariff structure, increasing access to credit, and reducing the cost of equipment.

Investment Concept: Solar Photovoltaic and Biogas Plants at the Samukh Agro-Energy Residential Complex

To support the NAMA concept developed for Azerbaijan, the construction of solar photovoltaic and biogas plants at the Samukh Agro-Energy Residential Complex is put forward as a viable proposal for investment. The opportunity falls under the jurisdiction of SAARES and includes financing of the construction and commissioning of two of the power plants that will be built during Phase 1 of the NAMA pilot at the Samukh Complex.

The investment in these facilities will result in increased technical experience with solar photovoltaic (PV) and biomass in the agriculture and rural residential sectors. As indicated in the NAMA, the total installed renewable energy capacity at Samukh is planned at 34.5 MW electric and 49 MW heat; the future agro-energy complexes at five selected replication sites are expected to be of similar size. The potential for scaling up the use of solar PV and biogas at other facilities is therefore significant if the Samukh pilot is successful. The investment activity will also serve as a pilot study on how to address some of the financial and regulatory barriers to be addressed in the NAMA.

The electricity and heat generated by the solar PV and biogas plants is expected to increase the availability and reliability of local energy sources. The improved availability of electricity supply will result in increased agricultural production, opportunity for expansion of small and medium enterprises, higher living standards through better infrastructure and lighting, and improved air quality by displacing fossil fuels. Other benefits include job creation during construction and income generation for the agricultural entities supplying the biomass which would otherwise be wasted. Social and environmental benefits will accrue to the national economy, such as savings in natural gas use for electricity generation.

By displacing the use of natural gas for electricity and heat generation, the investment project is expected to reduce GHG emissions. SAARES is conducting a feasibility study to determine the amount of heat and electricity to expect from solar PV and biogas plants. Once the feasibility study is completed the potential GHG savings can be calculated using the same approach and emission factors as those used for estimating the GHG abatement potential of the NAMA to promote renewable energy in Azerbaijan. This involves multiplying the kilowatt hour (kWh) electricity and megajoules heat produced with the respected emission factors for electricity and heat in Azerbaijan. The approach is documented in the TA document *Report on Nationally Appropriate Mitigation Actions (NAMAs) in Azerbaijan, Kazakhstan, and Uzbekistan*.[27]

[27] Manila. August 2015.

Technical Parameters

The Samukh district is located in northwest Azerbaijan. It is part of the Ganja-Gazakh economic region between the border with Georgia and Ganja. The total area of the district is 1,455 square kilometers (km^2) with a population of 56,300 as of 2014.

For the solar PV plant, SAARES expects to use the same technology which is already used at the Samukh Complex. The existing 2.8 MW plant consists of an array of polycrystalline panels with a unit capacity of 250 watts and cost about AZN500 ($524 equivalent). These panels are manufactured in Azerbaijan by the factory Azguntex, which is located north of the capital Baku.

For the biogas plant, SAARES developed cost and capacity estimations based on equipment produced by the Alten Group, a domestic subsidiary of United Enterprise International, a UK-registered company that promotes products and services from Azerbaijan abroad. SAARES may also use modules made by foreign manufacturers. The ongoing feasibility study will provide additional details.

Financial Parameters

SAARES is still conducting feasibility studies at Samukh. As a result, only limited cost data is available for the financial analysis of this investment note. The only firm numbers are the installed capacities for the PV and biogas plants (3.2 MW electric and 0.75 MW electric or heat) and the current electricity tariff for Azerbaijan (0.06 AZN/kWh or 0.063 $/kWh).

The financial analysis is based on the capacity and operations and maintenance (O&M) costs and availability factors for solar and biomass used in the national economic model for evaluating mitigation options in Azerbaijan's energy and transport sectors that was developed in the study (Table 15). This includes an assumed capacity cost for solar PV of 3,000 AZN/kW ($3,147). Using these assumptions, the capital costs for the proposed facility are $11.9 million for the solar PV portion and $4 million for the biogas cogeneration portion. This results in a total project cost of $15.9 million.

The cost of the solar PV plant is similar when the financial model is based on the cost of solar panels from Azguntex. Using Azguntex cost data, the net cost of the solar panels is $9.6 million. After adding the cost of construction and installation, which comprises at least a quarter of the total cost, the PV plant cost comes close to the model-based figure of $12 million.

SAARES expects to receive a little less than 60% of the funding for the NAMA and the Samukh pilot from international donors. Applying the same ratio of loan-to-total project cost, the amount of debt can be estimated at $9.6 million. The terms of the loan are assumed to be typical: 15-year maturity, 5-year grace period, interest rate of 1% or above,[28] and additional fees from the disbursing bank (origination, commitment, margin, and cost of guarantee) in the range of 0.3% to 3%. These assumptions lead to a loan with the true cost of credit of 139%, or an effective interest rate of 4.88% per annum.

[28] ADB. 2014d. *Overview of LIBOR-Based Loans: Sovereign and Sovereign-Guaranteed Borrowers.* Manila. January. Accessed August 2015 at http://www.adb.org/documents/overview-libor-based-loans-sovereign-and-sovereign-guaranteed-borrowers

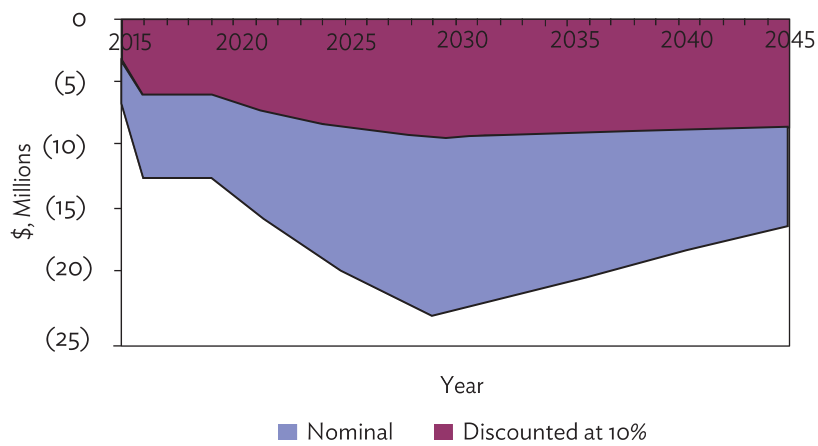
Table 15: Assumptions Used in Financial Analysis of the Solar Photovoltaic and Biogas Plants

Parameter, Unit	Value	Source
Electric generating capacity, solar PV, MW	3.2	SAARES
Electric generating capacity, biogas, MW	0.75	SAARES
Heat generating capacity, biogas, MW	0.75	SAARES
Electricity tariff, AZN/kWh	0.06	SAARES
Heat tariff, 2007 AZN/MJ	From 0.0052 in 2015 to 0.00595 in 2045	RETA 8119 Output 1 Economic model for Azerbaijan
Capital cost for solar PV (thousand 2007 AZN/MW)	2,926	RETA 8119 Output 1 Economic model for Azerbaijan. 3,334.69 in 2010, dropping to 884.71 in 2040
	Linear approximation for 2015	The range compares with estimations from other international literature and Asguntex cost of a unit panel (AZN500 for 250 W)
Capital cost for biogas electric capacity (thousand 2007 AZN/MW)	2,831.1	RETA 8119 Output 1 Economic model for Azerbaijan
Capital cost for biogas heat capacity (thousand 2007 AZN/MW)	1412.84	RETA 8119 Output 1 Economic model for Azerbaijan
Operating cost, solar PV (thousand 2007 AZN/MW/year)	1% of the capital cost, or 292.6	RETA 8119 Output 1 Economic model for Azerbaijan
Operating cost, biogas power (thousand 2007 AZN/MW/year)	98.73	RETA 8119 Output 1 Economic model for Azerbaijan
Operating cost, biogas heat (thousand 2007 AZN/MW/year)	14.12	RETA 8119 Output 1 Economic model for Azerbaijan
Load factor, solar PV, %	Estimated at 18	RETA 8119 Output 1 Economic model for Azerbaijan
Load factor, biogas electricity, %	79.5	RETA 8119 Output 1 Economic model for Azerbaijan
Load factor, biogas heat, %	62	RETA 8119 Output 1 Economic model for Azerbaijan
Commercial losses, %	3	Working estimate

AZN = Azerbaijan manat, kWh = kilowatt hour, MJ = megajoules, MW = megawatt, PV = photovoltaic, RETA = regional technical assistance, SAARES = Azerbaijan State Agency for Alternative and Renewable Energy Sources.

Source: ADB. 2015b. *Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: The Economics of Reducing Greenhouse Gas Emissions in the Energy and Transport Sectors*. Consultant's report. Manila (TA 8119-REG).

Figure 15: Cumulative Cash Flow of the Samukh Solar Photovoltaic and Biogas Plants Current Tariff of Azerbaijan Manat 0.06 per Kilowatt Hour



Source: ADB. 2015b. *Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: The Economics of Reducing Greenhouse Gas Emissions in the Energy and Transport Sectors*. Consultant's report. Manila (TA 8119-REG).

However, at the current electricity tariff the project is not financially viable. Annual revenues from the sale of electricity and heat (less than $700,000) cannot cover repayment of the principal alone ($956,000), even without accounting for operating expenses (Figure 15). No minor adjustments to assumptions on operating expenses, commercial losses, taxes, loan interest or value can change this. Only a change in the tariffs or the cost of project (mainly, equipment) can make it viable.

If the government increases tariffs from AZN0.06/kWh to AZN0.18/kWh,[29] the project internal rate of return (IRR) rises to 10.96%, the net present value (NPV) at a discount rate of 10% turns into $550,300 and the simple payback period becomes 15.5 years (Figure 16). This is the minimum tariff under which a discounted payback period of about 24 years falls within the lifetime of the project. Increasing the loan-to-project cost ratio also helps improve the viability of the project. If SAARES is able to secure a loan to cover 80% of the capital cost, the project IRR turns into 14.73% and the NPV to $1.55 million.

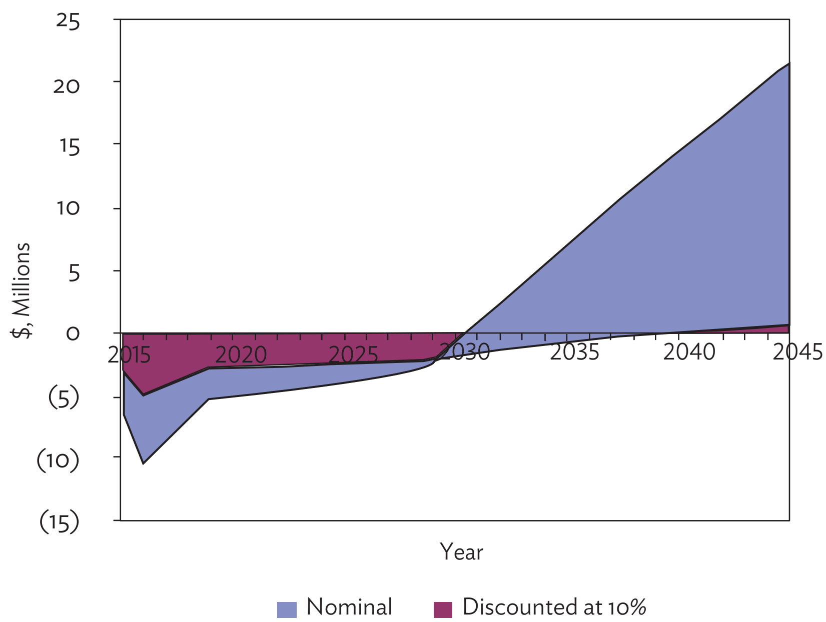
Implementation Arrangements

SAARES anticipates that the solar and biogas facilities will be commissioned by 2016. SAARES will operate the facilities and will enter into biomass supply arrangements with the agricultural entities selected to operate agricultural production at the Samukh Agro-Energy Residential Complex as well as other farms in the nearby region. SAARES owns the land upon which the Samukh Complex will be built and will lease it to the agricultural entities at terms to be specified.

The electricity and heat from the investment project will primarily be used for powering the agricultural and residential units at the complex itself. Any additional electricity from the solar

[29] Sales of heat contribute only about 20% to total project revenue.

Figure 16: Cumulative Cash Flow of the Samukh Solar Photovoltaic and Biogas Plants Electricity Tariff at Azerbaijan Manat 0.18 per Kilowatt Hour



Source: ADB. 2015b. *Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: The Economics of Reducing Greenhouse Gas Emissions in the Energy and Transport Sectors*. Consultant's report. Manila (TA 8119-REG).

PV and biogas plants will be used to meet demand from the neighboring city. The national utility, AzerEnerji, will link Samukh to these residential areas and will buy the surplus electricity from SAARES. SAARES is in the process of negotiating this arrangement with AzerEnerji.

Sensitivity Analysis and Risk Management

A simplified sensitivity assessment using the one-factor-at-a-time method identified the following risks (Table 16) which can be used to evaluate risk mitigation approaches for the investment opportunity. The potential risks are tied to electricity and heat tariffs, electricity production, investment cost, loan-to-project cost ratio, interest rates, and taxes. The parameters which are most affected by the risks are listed at the top in Table 16 while the ones with the least risk are listed at the bottom.

The analysis shows that a ±10% change to the electricity tariff is the most important factor determining the economic outcome of the project as it could result in a ±22% change in the IRR and a 244% change in the NPV. Finalizing the proposed revisions to the renewable energy tariffs in Azerbaijan is therefore important for determining the project financials. The heat tariff is less important since a relatively small part of the revenue comes from heat sales. In this case, a ±10% change only resulted in a 2% change in the IRR and 17% change in the NPV.

Investment costs, which to a larger degree are determined by the price of equipment, are also important. Here the impact ranges from 21% for the IRR to 222% for the NPV, indicating the impact of project economics is almost as important as the electricity tariff. Managing

Table 16: Sensitivity Analysis of the Samukh Solar Photovoltaic and Biogas Plants

Parameter (Change by +- 10%)	Outcome Change		Sensitivity	
	IRR, %	NPV ($)	IRR, %	NPV, %
Electricity tariff	+2.411 or -2.302	±1,342,732	±22	±244
Total investment cost	+2.63 or -1.973	±1,221,666	±21	±222
Total electricity production	±1.534	±869,474	±14	v158
Loan-to-project cost ratio	+0.767 or -0.548	±302,665	±6	v55
Profit tax	±0.438	±264,144	±4	±48
Heat tariff	+0.219 or -0.11	±93,551	±2	v17
Interest rate	±0.11	±49,527	±1	±9
Level of commercial losses	0	±16,509	±0	±3

IRR = internal rate of return, NPV = net present value.

Source: ADB. 2015a. *Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: Final Summary Report and Investment Concept Notes*. Consultant's report. Manila (TA 8119-REG).

the procurement process well is therefore important to ensure that the equipment budget is reasonable and that competitive bidding is used. Next on the sensitivity scale is the total amount of electricity produced by the project, with a resulting change to the IRR of 14% and NPV of 158%. There is typically a great deal of uncertainty regarding the amount of electricity and heat that can be produced by a biogas plant given access to and the quality of waste provided by agricultural enterprises. This risk will need to be factored into the project financials.

The rest of the parameters are less influential in terms of their impact on the economic outcome. In order of importance, these include loan-to-project cost ratio, profit tax, heat tariff, interest rate, and level of commercial losses.

In terms of risk management, both the capital cost of the project and applicable tariffs—at least for the near future—are to be determined before the project is implemented. There is a risk of equipment and construction cost overruns or equipment performance risks that can be dealt with by traditional strategies, such as binding contracts with guarantees and liquidated damage clauses, careful selection of suppliers and contractors, etc. However, the most serious risk is an unfavorable future change in the electricity tariff, which is more difficult to manage.

Cobenefits of the Investment Options

The electricity and heat generated by the solar PV and biogas plants is expected to increase the availability and reliability of local energy sources. The improved availability of electricity supply will result in increased agricultural production, opportunity for expansion of small and medium enterprises, higher living standards through better infrastructure and lighting, and improved air quality by displacing fossil fuels. Other benefits include job creation during construction and income generation for the agricultural entities supplying the biomass which would otherwise be wasted. Social and environmental benefits will accrue to the national economy, such as savings in natural gas use for electricity generation.

By displacing the use of natural gas for electricity and heat generation, the investment project is expected to reduce GHG emissions. SAARES is conducting a feasibility study to determine the amount of heat and electricity to expect from solar PV and biogas plants. Once the feasibility study is completed the potential GHG savings can be calculated using the same approach and emission factors as those used for estimating the GHG abatement potential of the NAMA to promote renewable energy in Azerbaijan.

Nationally Appropriate Mitigation Actions and Investment Concept Notes for Kazakhstan

Nationally Appropriate Mitigation Action Institutions

In Kazakhstan, the lead agency for nationally appropriate mitigation actions (NAMAs) is the Ministry of Energy (MOE), which is also responsible for national energy and electricity policy, low-carbon development, renewable energy, transition to a green economy, solid waste, and natural resources management. Two MOE departments—the Department of Climate Change (DCC) and the Department for Renewable Energy Supply (RES) Development—have been involved in NAMA proposals. The DCC is listed as the NAMA Approver for the United Nations Framework Convention on Climate Change (UNFCCC) NAMA Registry. So far, the DCC's role has focused on

(i) consideration of NAMA proposals prepared by other entities according to national sustainable development priorities and existing climate change policies,
(ii) submission of approved NAMAs to the UNFCCC Registry, and
(iii) support for and approval of measures to implement national and local climate change action plans.

To date, the government has focused on implementing key domestic climate change mitigation programs such as the emissions trading system (ETS) and the green growth concept; it has paid less attention to NAMAs. Nonetheless, stakeholders in the MOE and other agencies are interested in better understanding the concept, including how to prepare effective NAMA proposals, in case NAMAs can help attract financing for priority climate change programs.

A few international development partners have supported NAMAs in Kazakhstan through the following activities:

(i) The United Nations Development Programme (UNDP) has a project titled "Capacity-building for sustainable development through the integration of climate change issues into the strategic planning of the Republic of Kazakhstan" (2009–2012). One of the major project outcomes was the development of the Low-Carbon Development Plan of Kazakhstan until 2050. This plan aimed to reduce greenhouse gas (GHG) emissions without compromising economic and social development. To demonstrate practical steps for mitigating climate change, UNDP worked with stakeholders to develop two NAMA concepts ("Astana—A Low-Carbon City" and "Support for the Solar Industry"), which were approved by the city of Astana and the MOE; and

(ii) Kazakhstan is participating in a regional project implemented by the GIZ titled "Capacity Development for Climate Policy in the Western Balkans, Central and Eastern Europe and Central Asia." The project began in 2013 and continues through 2017. It targets Azerbaijan, Belarus, Croatia, Georgia, Kazakhstan, the Kyrgyz Republic, Montenegro, the Russian Federation, Serbia, Turkmenistan, Ukraine, and Uzbekistan. In Kazakhstan, the project assists with implementation of the ETS and delivers regional capacity building workshops on NAMA design.

Existing Nationally Appropriate Mitigation Action Proposals

UNDP developed two NAMAs, which the MOE submitted to the UNFCCC in 2014. At the time of writing this report, only the Low-Carbon City NAMA had been uploaded to the NAMA Registry website.[30]

1. Astana: A Low-Carbon City NAMA (or Urban NAMA Astana)—will introduce cross-sectoral interventions that result in sustainable growth and healthy urban living conditions, with the creation of the Astana Green Growth Centre out of the Mayor's office serving as the implementing agency for the NAMA.
2. Support for the Solar Industry NAMA—calls for (i) creation of a new and dedicated institution; (ii) provision of geographic data on solar energy potential; (iii) improvement of the feed-in-tariff; (iv) provision of financial incentives for solar power, and (v) construction of 200 megawatts (MW) of solar power capacity by 2020 (1% of 2012 capacity).

Background and Rationale

Kazakhstan relies mainly on gasoline and diesel for transport. The share of natural gas in total fuel consumed is below 1%.[31] One of the reasons for the low penetration of natural gas is insufficient refueling infrastructure. The potential for increasing the use of natural gas is large and is a priority to the government given the vast domestic supply of cheap, domestic natural gas and the fact that Kazakhstan has to rely on imports for 34% of gasoline and 9% of diesel fuel. Kazakhstan's reserves of natural gas are estimated at 1.3 trillion cubic meters (m^3).[32]

[30] The NAMA Registry. 2014. *NS-124 – Nationally Appropriate Mitigation Actions for Low-Carbon Urban Development in Kazakhstan.* Accessed (date) at: http://www4.unfccc.int/sites/nama/_layouts/un/fccc/nama/NamaSeekingSupportForPreparation.aspx?ID=66&viewOnly=1

[31] ADB. 2015. *Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan, and Uzbekistan: Options and Costs.* Consultant's report. Manila (TA 8119-REG).

[32] Government of Kazakhstan, Ministry of Industry and New Technologies. 2014. *Draft Concept on Fuel and Energy Development to 2030 for Kazakhstan*; and BP. 2014. *BP Statistical Review of World Energy 2014.*

Compressed natural gas is much cheaper than gasoline and diesel in Kazakhstan (Appendices of ADB [2015b]). The price of natural gas and compressed natural gas (CNG) has remained much more stable than the price of oil-based fuels and is expected to remain low for the next decades. Given the low cost of CNG, this fuel provides an attractive alternative for many vehicle applications if the necessary engine technologies and infrastructure to support refueling were available. This is particularly the case for operators of large fleets, such as municipal buses, trucks, and taxis, which can accommodate the required engine size and are able to refuel at centralized stations.

Proposed Nationally Appropriate Mitigation Action: Fostering Use of Natural Gas in the Transport Sector

The goal of this NAMA is to reduce GHG emissions and decrease air pollution by switching from gasoline and diesel to natural gas as a fuel for the transport sector. The fuel switch will result in reductions of carbon dioxide and nitrous oxide.

The NAMA will support the government's goal of increasing the use of Kazakhstan's cheap and clean natural gas for transport. It will do this by first developing the infrastructure to supply CNG throughout the country and later also developing the infrastructure for liquefied natural gas (LNG). The national gas operator Joint Stock Company (JSC) KazTransGas will implement the NAMA by

- (i) constructing a network of 35 to 100 CNG fueling stations;
- (ii) creating other infrastructure to enable a natural gas market in Kazakhstan (e.g., workshops for converting existing vehicles to CNG, testing and certification centers, training facilities); and
- (iii) extending natural gas to nontraditional transport areas.

In addition to investment in specific sites and projects, the NAMA will enable development and implementation of a comprehensive program for natural gas fuel promotion, including a package of government support measures; formulation of technical and regulatory norms, protocols, or documents; and development of the necessary institutional and human capacity to support a switch to natural gas.

Kazakhstan's reserves of oil, natural gas, coal, ores, and minerals are plentiful. It has ample areas suitable for agriculture and an educated population. However, the country's huge territory and low population density (one of the lowest in the world) present developmental challenges and ensure that the transport sector will always be an important and, for the foreseeable future, growing part of the national economy.[33]

The number of vehicles on the road has more than tripled since 2000 and is expected to continue to grow. As a result, GHG emissions and local air pollutants will also increase significantly unless major measures are implemented to improve efficiency and switch to low-carbon fuels. In line

[33] Government of Kazakhstan. 2014. *Decree of the President No. 725 on GOK Program of Development and Integration of Transport System in the Republic of Kazakhstan up to 2020*. 13 January. Accessed at: http://www.akorda.kz/upload/%D0%96%20%E2%84%96%20725%20%D1%80.pdf; The program itself is available at: www.mid.gov.kz/images/stories/contents/gp_150520141656.pdf

with national strategic objectives to increase the use of natural gas and slow the growth in GHG emissions, the NAMA proposes to foster a modern, efficient, low-carbon transport system based on the use of CNG as a major transport fuel.

The transport sector is based primarily on traditional fuels—gasoline and diesel. The share of natural gas in total fuel consumption is less than 1%. One of the reasons for the low penetration of natural gas is insufficient infrastructure for this fuel. Meanwhile, the potential for increasing the use of natural gas is large; it is a priority for the government, given the country's vast supply of cheap, domestic natural gas and its reliance on imports for 34% of gasoline and 9% of diesel fuel. To address the infrastructure problem and ensure development of a clean transport sector in accordance with national priorities, the NAMA will support the natural gas company, JSC KazTransGas, in constructing a network of up to 100 CNG refueling stations and creating other elements of the infrastructure for a natural gas refueling market in Kazakhstan.

Greenhouse Gas Emissions Reductions

The NAMA concept will increase the use of natural gas in the transport sector and reduce the use of diesel and gasoline, both of which have a higher carbon content than natural gas. This fuel switch will result in reductions of two GHGs: carbon dioxide and nitrous oxide.

Without the NAMA, Kazakhstan will continue to use mostly diesel and gasoline for transport, and investment in new natural gas refueling infrastructure will remain low. Meanwhile, the need for transport will continue to grow along with Kazakhstan's improving economy. Therefore, the assumption is that in the baseline (without the NAMA) the share of natural gas in transport will continue to stay below 1% of total energy demand.

Using the economic model developed for the energy and transport sectors of Kazakhstan, the study team estimated the annual baseline GHG emissions for vehicle transport in Kazakhstan (Appendices of ADB [2015b]). The estimate covers fuel switching in vehicles for road transport, as the use of natural gas for shipping and rail transport is still under consideration by the government and therefore cannot be quantified. The GHG emission reduction estimate also considers a second scenario where an increasing number of cars, buses, and trucks are converted to CNG during the life of the NAMA resulting in a conversion of 8% of all vehicles on the road in 2025.

Cobenefits of the Proposed Nationally Appropriate Mitigation Action

In addition to significantly reducing GHG emissions in the transport sector and promoting sustainable development, the NAMA is expected to create the following cobenefits:

(i) reduced local air pollution;
(ii) health cobenefits from reduced local air pollution;
(iii) increased energy security;
(iv) income and job generation;
(v) increased disposable income due to reduced fuel costs;
(vi) increased private enterprise in fields related to fuel switching and vehicle conversions;
(vii) accelerated turnover of outdated vehicle stock (e.g., through imports of original equipment manufacturer of CNG vehicles); and
(viii) development of domestic CNG vehicle production capacity (eventually) with potential for exports.

A large portion of this NAMA involves creating the supporting infrastructure and regulatory framework for natural gas vehicles. Although these activities will not directly lead to GHG emission reductions, they will result in a general improvement in market penetration by natural gas for transport and other uses, which can be tracked by analyzing the overall share of natural gas in energy and transport.

In addition, by building LNG production plants in Kazakhstan (and constructing the associated network of LNG refueling stations in five regions that do not currently have natural gas infrastructure), the NAMA will facilitate general fuel switching away from coal and diesel and enable CNG refueling stations to be introduced for road transport. Because LNG will be delivered for regasification on the spot, residential buildings, industry, and small and medium-sized businesses in remote areas will be able to replace coal and diesel with natural gas. This includes using natural gas in boiler houses for heat generation. However, potential emission reductions cannot be calculated until the specific distribution of various end uses is determined.

Barriers That Would Be Addressed by the Nationally Appropriate Mitigation Action

Natural gas has a number of economic benefits in Kazakhstan, such as providing a more reliable, long-term domestic supply of fuel with a much lower, less volatile price. In addition to its pollution-control benefits (as it emits lower levels of GHGs and air pollutants than traditional transport fuels), natural gas is safe and well-suited for vehicles driven under the local climate extremes found in Kazakhstan. Moreover, the government has explicitly stated its support for wider use of natural gas.

Despite these advantages, however, there are still many barriers preventing widespread adoption of natural gas, including those summarized below.

(i) **Economic barriers.** In trying to develop the CNG infrastructure, Kazakhstan faces the hurdle of needing to reach a minimum penetration threshold. To interest end-users in CNG, there needs to be a CNG support system (conversion facilities, fueling stations, service providers). However, for this support system to become a viable investment opportunity, there must be a sufficiently large number of CNG end-users. The government is trying to resolve this problem by adopting an action plan for switching vehicles to environmentally friendly fuels and similar programs,[34] but other budget priorities and the high cost of installing CNG refueling stations makes it difficult to stage the massive and swift roll-out campaign needed to overcome the barriers to initial acceptance.

(ii) **Administrative barriers.** Existing rules and restrictions on budget procurement for every project component (siting and zoning, equipment acquisition, tenders for service contracts) create administrative barriers. These barriers delay project implementation beyond any reasonable timeframe. On the other hand, if CNG project developers attempt to avoid relying on the budget, they will face barriers to private financing. They will discover that few lenders and investors are ready to get involved in introducing and

[34] Government of Kazakhstan. 2014 Decree No. 969 on *Amendments on adoption of Action Plan to implement Green Economy Concept 2013-2020, related to the Action Plan for switching vehicles to environmentally-friendly fuels, creation of associated infrastructures and introduction of electro mobiles.* 4 September. Accessed at: http://tengrinews.kz/zakon/docs?ngr=P1400000969

promoting a new engine fuel in Kazakhstan, since it will be perceived as having risks too difficult to foresee and manage.

(iii) **Regulatory barriers.** Regulations also play a role in impeding the advance of CNG in Kazakhstan. Firstly, there are no national standards or rules for construction and operations and maintenance of CNG fueling stations or multifuel refueling stations. To build and operate CNG fueling stations, JSC KazTransGas had to prepare a request to develop and approve these normative regulations at its own cost.

(iv) **Informational barriers.** There is no widespread informational support for developing the natural gas vehicle (NGV) sector. Decision makers—even those familiar with and supportive of natural gas as an environmentally friendly fuel—are not fully informed about the current state of existing technologies and opportunities. Even the proponents of NGV interviewed by this project team were not always aware of each other's efforts or of the different technological approaches being pursued by different companies.

(v) **Psychological barriers.** These barriers are not as prominent as might be expected given negative public impressions stemming from unsuccessful attempts to introduce CNG vehicles 30 year ago. The equipment of that period led to safety, dependability, and environmental problems. Private car owners in Kazakhstan today are quite open to modern natural gas-powered vehicles. Existing conversion shops report a backlog of orders.

(vi) **Institutional barriers.** Kazakhstan currently has limited human capacity to support a switch to NGVs. There is an insufficient supply of skilled labor, and the few specialists who are available need more education and experience. Currently there are no training programs for CNG fueling station operators and there are very rudimentary educational resources for specialists to learn to convert existing vehicles to NGVs. The only oversight or testing is done by authorities in the areas of safety and emergency responses. While necessary, this oversight and testing cannot substitute for professional teaching of proper operations and maintenance for complicated modern equipment.

Investment Concept

The investment opportunity described in this concept note is part of the NAMA proposed by the natural gas JSC KazTransGas to foster the use of natural gas for transport in Kazakhstan. JSC KazTransGas will be the implementing agency for the opportunity which includes the construction of a network of 10 CNG refueling stations. The opportunity also includes soft components such as technical training on how to convert existing vehicles to CNG, creation of testing and certification centers, and introduction of training facilities for technicians who convert and maintain the vehicles.

The investment covers two phases of NAMA implementation (2014–2018). The expected outcomes of the investment are

(i) construction of 10 CNG fueling stations in different locations of Kazakhstan;
(ii) completion of a feasibility study for the construction of additional 35 CNG refueling stations;

(iii) provision of market research;
(iv) retrofitting of the corporate fleet of JSC KazTransGas which includes 260 vehicles completed;
(v) establishment of a center for technical inspection of natural gas equipment, primarily high-pressure cylinders for CNG;
(vi) training of personnel (250 persons); and
(vii) introduction of new standards and norms, and improvement of the legislative framework for CNG and LNG vehicles.

Technical Parameters

The investment concept involves the construction of 10 new CNG fueling stations (Figure 17) in the following cities:

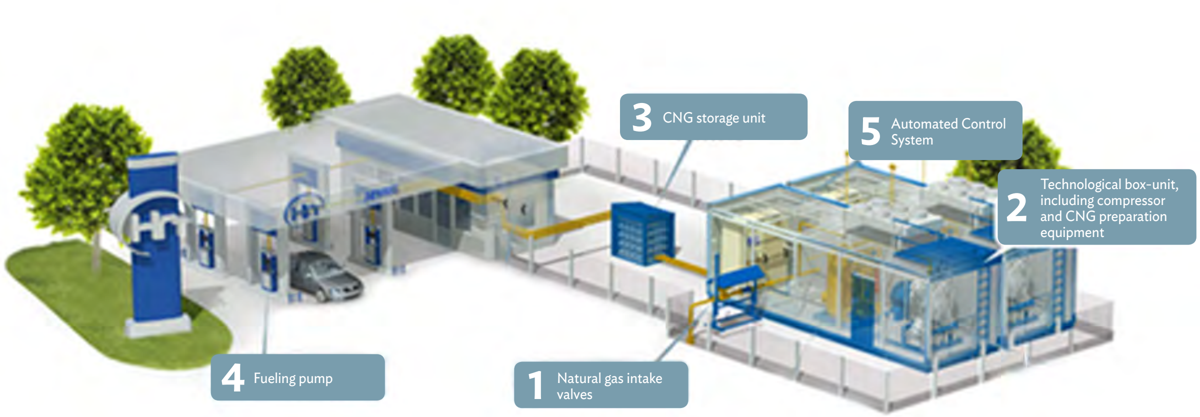
(i) Kyzylorda, Shymkent, Actobe (2015–2017);
(ii) Taraz, Uralsk, Kostanai, Atyrau, Aktau (2016–2017); and
(iii) Merke and Turkestan (2017–2018).

This will be the first subset of the 35 fueling stations to be sited as part of the NAMA, according to the results of a market and feasibility study being conducted by JSC KazTransGaz.

Financial Parameters

Where specific data was lacking for the financial analysis, assumptions based on the experience gained from the ongoing construction of three CNG fueling stations in the cities of Actobe,

Figure 17: Working Design of a Compressed Natural Gas Fueling Station with Refueling Capacity of 2100 Cubic Meters per Hour



CNG = compressed natural gas.
Source: Joint Stock Company KazTransGas.

Kyzylorda, and Shymkent, were used. When there is no site-specific data (land plot, equipment, staff schedule, and initial expenses), the cost and productivity data analyzed in detail for each of the three refueling stations under construction is averaged and extrapolated to the other seven CNG refueling stations to be funded as part of this investment concept.

The cost and economic indicators for CNG refueling stations under construction are presented in Table 17. Despite the fueling stations being identical in design, the separate subprojects have internal rate of return ranging from 18% to almost 26%. This is because both fixed and variable costs of installing and running the fueling stations depend on a specific site. They also differ according to the sales price of CNG and the purchase price of raw natural gas, which is determined by the proximity of natural gas deposits and relevant infrastructure to the fueling station, as well as the local "demand/supply" balance for gas.

JSC KazTransGaz manages some of this price uncertainty by entering into long-term contracts for raw natural gas which, together with the expected long-term stability of CNG prices, enables the company to protect its margins. However, regional price differentials will still need to be considered. A full feasibility study for this investment opportunity should therefore draw heavily on the results of the market analysis.

For the three CNG fueling stations, the total investment cost is $7,095,000 and the combined project IRR is 18.81%. The simple payback period for the project is 5 years, while the discounted payback period is 6 years. The proposed investment into all 10 refueling stations should yield similar results.

Table 17: Economic and Technical Indicators for Compressed Natural Gas Fueling Stations Under Construction

	City		
Indicator	Shymkent	Kyzyl-Orda	Actobe
Total investment cost, $	2,283,345	2,412,934	2,398,700
Fueling capacity, 1000 m^3/hour	2,100	2,100	2,100
Maximum daily fueling capacity, 1000 m^3	12,264	12,264	12,264
Average CNG-FS load factor, %	65	55	53
CNG sale price range during project period (2015–2030), $/$m^3$	0.26–0.56	0.26–0.42	0.29–0.42
Purchase price range for natural gas during project period (2015–2030), $/$m^3$	0.14–0.36	0.07–0.19	0.04–0.11
Net present value at discount rate 11.5%, $	839,465	978,553	1,787,968
Internal rate of return, %	18.18	20.12	25.86
Simple payback period, years	5	5	4
Discounted payback period, years	7	6	5

CNG = compressed natural gas, FS = fueling station, m^3 = cubic meter.

Source: ADB. 2015a. *Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: Final Summary Report and Investment Concept Notes*. Consultant's report. Manila (TA 8119-REG).

The investment concept includes investment into some of the soft components of the NAMA, including:

(i) a full feasibility study of all of the 35 fueling stations envisaged by the NAMA,
(ii) development of a design for a CNG refueling station best suited for the climate and other characteristics of Kazakhstan,
(iii) construction of a testing and certification center for CNG high-pressure tanks and other equipment,
(iv) education and training of specialists in the natural gas fields, and
(v) general capacity building.

The total funding required for the soft components is $6.5 million. These activities were judged to be necessary for the success of the NAMA and the development of a natural gas-based transport sector. They are therefore included with this investment concept. The soft components can be financed internally (from the proceeds of this investment opportunity) or rolled into the loan. Both scenarios are reflected and analyzed in the financial model below. Additionally, the soft components may be partially or fully funded by grants or technical assistance from donors. If this is the case, it is easy to reflect this change in the financial model by reducing this component cost by the amount received as grants.

With no investment into soft components, the total capital cost of the 10 CNG fueling stations is estimated at $18.9 million. With the soft components included, the total required funding becomes $25.4 million. Given the funding requests for Phases 1 and 2 of the NAMA (Table 18), the ratio of the loan to the total cost desired by the sponsors is 62.5%. Therefore, the project sponsors are seeking a loan in the amount of $15.9 million (with the soft components fully rolled in) or $11.8 million (without soft components), a 15-year maturity, and a 5-year grace period. Since the life of the CNG equipment is limited to about 15 years, KazTransGas Onimderi considers the lifetime of the project to be 15 years. This number is used as the time horizon for the analysis.

Table 18: Funding Request from Joint Stock Company KazTransGas for Phases 1 and 2 of the Nationally Appropriate Mitigation Action

Phase	Year	Description	Total Cost ($)	Including		
				State Budget ($)	Own Capital ($)	International Donors ($)
1	2014–2015	Pilot market infiltration	10,425,000	180,000	6,890,000	3,255,000
2	2016–2018	Extending compressed natural gas to medium and small commercial entities	30,500,000	250,000	7,930,000	22,320,000

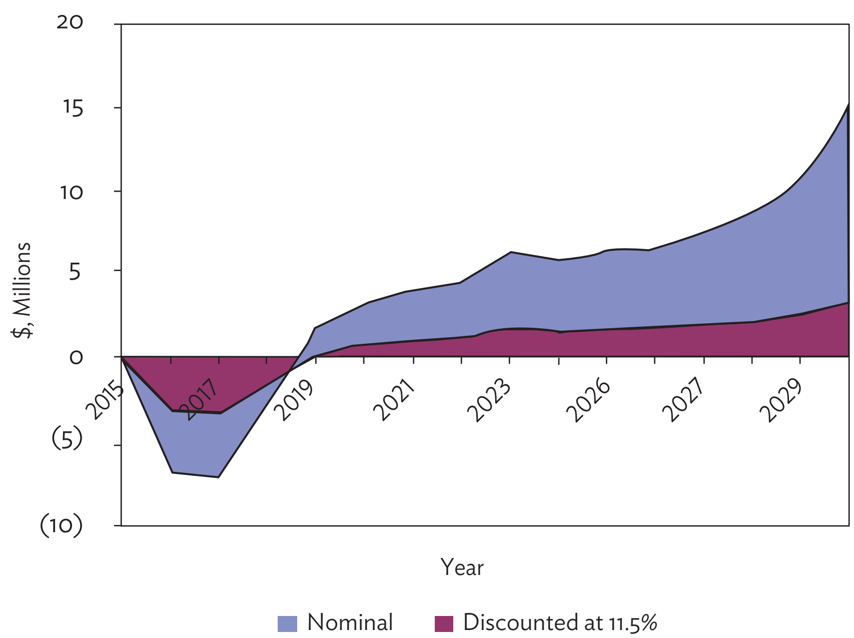
Source: ADB. 2015a. *Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: Final Summary Report and Investment Concept Notes.* Consultant's report. Manila (TA 8119-REG).

Using the JSC KazTransGaz forecast for CNG tariffs and purchase price of natural gas at each location (specific numbers until 2026 and then 7% escalation rate, in line with the inflation forecast), the cash flow analysis for the loan with the soft components included produces an IRR of 29.86% and an NPV of $3,307,706. This assumes a discount rate of 11.5%, which is the average cost of capital for KazTransGaz Onimderi. Both the simple and discounted payback periods are less than 4 years. The cumulative cash flow in nominal and discounted dollars is shown in Figure 18.

The irregular shape of the curves, with a decrease in accumulated cash in 2024, as well as the discrepancy between the relatively short payback period and the low NPV, reflect the peculiarities of the forecast for CNG tariffs and the cost of natural gas used by JSC TransKazGas.

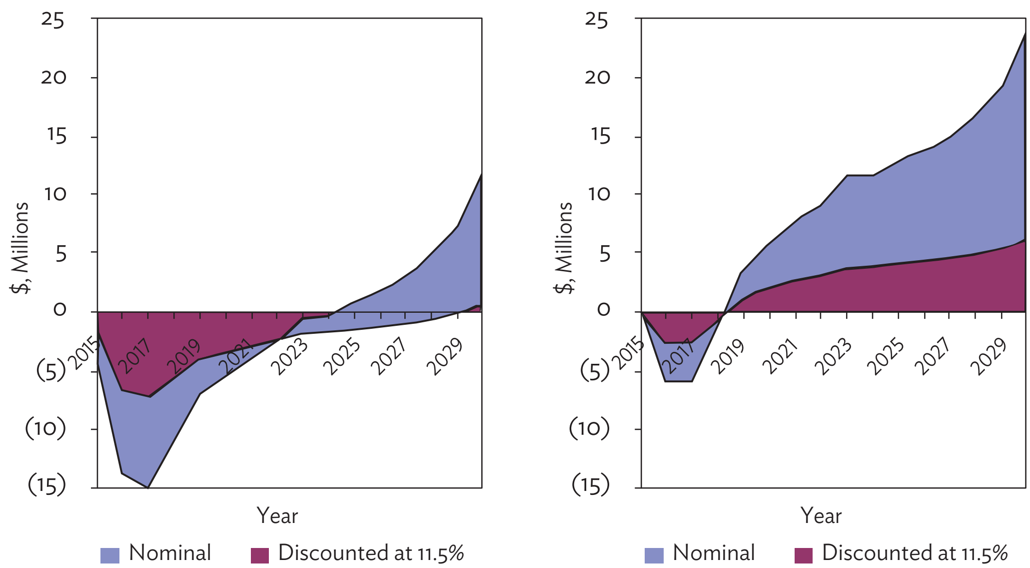
If the loan covers only part or no cost of the soft components, the economics of the project worsen. When the project is forced to cover the full cost of the soft component from its cash flow, the IRR decreases to 12.93% and NPV to $594,656 (see the cumulative cash flow in Figure 19A). Simple payback period becomes more than 9 years, while the discounted payback is over 14 years. Alternatively, if the full cost of the soft components is absorbed by the third parties (grants, technical assistance), the economic indicators of the project improve drastically. In this case, the IRR is at 43.37%, NPV is at $5.98 million and both simple and discounted payback periods are just over 3 years (see the cash flow in Figure 19B).

Figure 18: Cumulative Cash Flow of the 10 Compressed Natural Gas Fueling Stations with the Full Cost of Soft Components Rolled into the Loan



Source: ADB. 2015a. *Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: Final Summary Report and Investment Concept Notes*. Consultant's report. Manila (TA 8119-REG).

Figure 19: Cumulative Cash Flow of the 10 Compressed Natural Gas Fueling Stations with the Soft Components Fully Funded by Third Parties



Source: ADB. 2015a. *Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: Final Summary Report and Investment Concept Notes*. Consultant's report. Manila (TA 8119-REG).

Implementation Arrangements

The lifetime of the project is 15 years, starting in 2016. The proposed loan disbursement schedule assumes that the first three refueling stations are built during 2016, the next five are constructed during 2016–2017, and the last two in 2017–2018.

KazTransGas Onimderi, as the executing agency for the natural gas NAMA, will be responsible for project execution, reporting, and coordination of activities among implementing partners. Staff from KazTransGas Onimderi will work directly with JSC KazTransGas on matters related to general management and oversight, financial review, and approval of project investments.

KazTransGas Onimderi will prepare monitoring reports for JSC KazTransGaz which will then pass these on to relevant stakeholders, such as:

(i) The Ministry of Finance and the Ministry of Economy regarding the use of funds from the State Budget;
(ii) International donors and the Ministry of Energy for potential reporting to the UNFCCC; and
(iii) The Ministry of Innovation Development via the "Institute of Power Development and Energy Saving" regarding potential energy efficiency improvements in transport.

Sensitivity Analysis

Analysis of the data from the CNG fueling stations in Actobe, Kyzyl-Orda, and Shymkent indicates that the economic outcomes of the fueling stations are most sensitive to changes in the volume of CNG sold and fluctuation of the sale price. These risks, unfortunately, are not under the direct control of the fueling station operators. However, to a degree they counterbalance one another. When the sale price is lower, the revenue from fueling a single car decreases. However, in the long run, a lower CNG price will improve the desirability of natural gas vehicles. As a result, a bigger number of people or enterprises will convert their cars to natural gas, spurring the growth of the market base of CNG fueling stations.

The profitability of the fueling stations is also sensitive to the wholesale price of natural gas. Other parameters, like cost of electricity, are responsible for smaller impacts on project viability.

Cobenefits

This investment opportunity focuses on the construction of refueling infrastructure and capacity building. Therefore, it does not lead to direct GHG emission reductions. However, it indirectly supports the implementation of the NAMA to foster natural gas for transport, which is estimated to result in GHG emission reductions ranging from 135,315 tons of carbon dioxide equivalent (tCO_2e) to 1,766,574 tCO_2e per year by 2025, depending on the amount of NAMA support obtained. These reductions are expected to come from the conversion of diesel buses and trucks and gasoline cars to CNG.

Realization of the suggested investment opportunity will provide the following cobenefits:

(i) Health benefits from reduced local air pollution, especially in congested urban areas;
(ii) Increased energy security;
(iii) Income and job generation;
(iv) Increased disposable income due to reduced fuel costs;
(v) Private sector development in fields related to fuel switching and vehicle conversions;
(vi) Accelerated turnover of outdated vehicle stock and potential import of original equipment manufacturer natural gas vehicles; and
(vii) Eventually, development of domestic natural gas vehicle production capacity, including for potential export.

Nationally Appropriate Mitigation Actions and Investment Concept Notes for Uzbekistan

Nationally Appropriate Mitigation Action Institutions

The Government of Uzbekistan is receptive to the nationally appropriate mitigation action (NAMA) concept but has not yet clarified institutional arrangements for evaluating and implementing NAMAs.[35] The government has delegated functions related to the United Nations Framework Convention on Climate Change (UNFCCC) and the Kyoto Protocol to Uzhydropowermet, which is also listed as the NAMA Approver with the UNFCCC NAMA Registry. Uzhydropowermet prepares the national greenhouse gas (GHG) emissions inventory and national communications for submission to the UNFCCC.

International development partners have supported the design of NAMAs in the following ways:

(i) Through a joint United Nations Development Programme (UNDP)/Ministry of Economy project titled "Supporting Uzbekistan in Transition to a Low-Emission Development Path," UNDP is investigating the potential for NAMAs in buildings and evaluating potential institutional arrangements for NAMAs. As part of its work, UNDP published two Russian-language publications related to NAMAs:
   a. A Road Map—The Transition from the CDM (2014)
   b. Guidelines on NAMAs (2014)

   Both documents propose a legislative arrangement for NAMAs, which the government is now considering.

[35] ADB. 2015a. *Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: Final Summary Report and Investment Concept Notes*. Consultant's report. Manila (TA 8119-REG).

(ii) Along with Azerbaijan and Kazakhstan, Uzbekistan is participating in a regional project implemented by the GIZ titled "Capacity Development for Climate Policy in the Western Balkans, Central and Eastern Europe and Central Asia." The project delivers regional capacity building workshops on NAMA development. These workshops have included representatives from Uzbekistan.

Uzhydropowermet, in collaboration with the State Nature Protection Committee, has established a working group to prepare an Intended Nationally Determined Contribution (INDC) ahead of the UNFCCC Conference of Parties 21 in Paris. The working group is receptive to incorporating NAMAs into the INDC if they are finalized before the INDC is submitted to the UNFCCC.

Existing Nationally Appropriate Mitigation Action Proposals

With assistance from international development partners, national stakeholders have proposed two NAMAs. A third is under development. The first NAMA, developed with support from the German government, focuses on energy-efficient rehabilitation of multistory residential buildings. Uzkommunkhizmat would be the implementing partner. The second NAMA is being developed under the UNDP/Ministry of Economy project "Supporting Uzbekistan in Transition to a Low-Emission Development Path." It targets energy efficiency in rural buildings. The Asian Development Bank (ADB) is working with the Ministry of Economy and Uzbekenergo to develop a NAMA based on the country's solar road map. At the time of writing this report, none of these NAMA concepts have been submitted to the NAMA Registry.

Background and Rationale

Uzbekistan obtained independence after the dissolution of the Soviet Union. Since then, the country has been trying to find the optimal path to a market-based economy that provides for the needs of its population while taking into account major social and environmental constraints, including climate change. Energy and the power sector have provided the backbone of the economic development experienced since the initial economic contraction of the early 1990s. As a result, GHG emissions have increased and are expected to continue to do so over the next couple of decades.

The energy resources in Uzbekistan are plentiful, with natural gas representing over 80% of the total energy mix. However, given both environmental considerations and the potential value of natural gas or oil as export resources, the country has been making efforts to increase the role of renewable energy, including utilization of small hydropower plants (SHPs). Other development priorities for the energy sector include

(i) rehabilitating existing power plants,
(ii) promoting energy savings and energy efficiency,
(iii) electrifying railroads, and
(iv) increasing the use of natural gas in transport and power generation.

The government prioritizes rehabilitation of existing plants and expansion of renewable energy, since they contribute to energy security and energy independence while also reducing emissions.

Uzbekistan has considerable fossil fuel reserves. However, given the potential value of natural gas and oil as export resources, the country has been making efforts to switch to renewable

Table 19: Potential Renewable Resource Yields in Uzbekistan

Resource	Annual Yield (billion kWh)
Biomass[a]	3.5
Hydropower[a]	20.9
Solar[a]	2,055.0
Wind[a]	4.6
Total Primary Energy Supply (TPES) in 2010[b]	492.0

kWh = kilowatt hour.

Sources:

[a] Centre of Hydrometeorological Service. 2008. Second National Communication of the Republic of Uzbekistan under the United Nations Framework Convention on Climate Change. http://unfccc.int/resource/docs/natc/uzbnc2e.pdf

[b] ADB. 2015b. *Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: The Economics of Reducing Greenhouse Gas Emissions in the Energy and Transport Sectors*. Consultant's report. Manila (TA 8119-REG).

energy for power generation. As presented in Table 19, Uzbekistan has significant renewable energy potential, particularly solar and hydropower. Utilization of small hydropower is of interest to the government because it can provide low-cost, low-environmental impact electricity, particularly in remote regions where there are problems with dependable and high-quality power supply.

Hydropower represents less than 15% of total electricity generation, with the share of SHPs at just 10% of all hydropower or less than 1.5% of total power production. The technical potential for hydropower generation in Uzbekistan is estimated at 20.9 billion kilowatt hours (kWh) per year. Only a quarter of this potential is used. About a third of the unused potential is related to agricultural infrastructure (i.e., irrigation channels and water storage facilities) where SHPs are a fitting solution. The small hydropower potential includes viable SHP sites at least at 1,100 small rivers, 42 reservoirs, and 98 main irrigation channels.[36]

Two state-owned entities are involved in hydropower generation: the State Joint Stock Company "Uzbekenergo," which is directly controlled by the Government of Uzbekistan and a specialized enterprise "Uzsuvenergo," which is under the jurisdiction and control of the Ministry of Agriculture and Water Resources (MAWR). Uzbekenergo is in charge of all the hydropower plants on natural water streams and reservoirs. Uzsuvenergo is tasked with the construction and operation of hydropower plants (HPPs) at irrigation channels and other agricultural infrastructure.

On 5 May 2015, Uzbekistan President I. Karimov signed Resolution 2343 "On the Program of Measures to Lower Energy Intensity and Implement Energy Efficient Technologies and Systems in the Economy and Social Sphere from 2015 to 2019." The resolution requests the Ministry of Economy, Ministry of Finance, MAWR, Uzbekenergo and the design institute "Hydroproject" to

[36] UNESCO, 2010. *Use of Renewable Energy Sources in Central Asia.* http://www.un.org.kg/index2.php?option=com_resource&task=show_file&id=14722

develop the State Program for Development of Hydro Power for 2016–2020. The program must be approved by the end of 2015. Existing drafts of the program, written earlier by Uzbekenergo, foresee construction of 76 new HPPs with a total generating capacity of 2,512 megawatts (MW) and rehabilitation of 33 existing HPPs.

Also in 2015, a separate Program for Development of Small Hydro during 2015–2030 was developed by MAWR and is going through the appraisal process within the government. This program provides for the construction of 19 SHPs with a total capacity of 210 MW and requires the investment of $727.2 million. With the passing of Resolution 2343 and approval of the Roadmap, this program with adjustments will likely become a part of the wider program of hydropower development for 2016–2020.

Proposed Nationally Appropriate Mitigation Action—Accelerating Deployment of Small-Scale Hydropower in Uzbekistan

The goal of this NAMA is to accelerate and expand the development of small hydropower in Uzbekistan by supplementing governmental plans for implementation with analysis and comprehensive identification of steps to accelerate that implementation. This includes clarifying the institutional arrangements governing small hydropower; modifying the tariff structure to incentivize investment; improving technical skills for evaluating, planning, and constructing SHPs; and introducing measures to accelerate the utilization of public and private capital to finance planned hydropower capacity.

For this NAMA, small hydropower is defined as hydropower plants with installed capacity of less than 30 MW. The acceleration of the rehabilitation and construction of these plants in Uzbekistan will avoid the use of fossil fuel-based electricity generation, thereby decreasing emissions of three GHGs: carbon dioxide, methane, and nitrous oxide.

Greenhouse Gas Emissions Reductions

When all 19 SHPs are commissioned and 3 existing HPPs are rehabilitated, the displaced electricity generation will result in estimated GHG emission reductions of 918,715 tons of carbon dioxide equivalent (tCO_2e) per year by 2030 and cumulative GHG emission reductions of 7,396,414 tCO_2e during the 2015–2030 lifetime of the NAMA.

Without the NAMA, it is expected that the key barriers to increasing investment in small hydropower will remain unresolved and will continue to prevent investment in new and rehabilitated capacity. Therefore, the assumption is that in the baseline without the NAMA the existing fuel mix will continue to produce the required electricity. If fully implemented by 2030, the NAMA will result in a 2.2% annual reduction in GHG emissions compared to the baseline for electricity generation (Table 20).

Table 20: Annual Greenhouse Gas Emission Reductions from Electricity Generation in Uzbekistan with the Nationally Appropriate Mitigation Action, 2015–2030

	Year				
	2015	2020	2025	2030	Cumulative Total (2015–2030)
GHG emissions from electricity generation in Uzbekistan (tCO_2e)	33,224,917	31,110,579	34,051,761	40,865,485	540,061,088
GHG emission reductions from introducing the NAMA (tCO_2e)	0	−359,990	−602,842	−918,715	−7,396,414
% Change from baseline	0.0	−1.2	−1.8	−2.2	−1.4

GHG = greenhouse gas, NAMA = nationally appropriate mitigation action, tCO_2e = tons of carbon dioxide equivalent.

Source: ADB. 2015c. *Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: Report on Nationally Appropriate Mitigation Actions*. Consultant's report. Manila (TA 8119-REG).

Cobenefits of the Nationally Appropriate Mitigation Action

Implementation of the NAMA will produce the following cobenefits:

(i) reduced emissions of local air pollutants and associated negative health effects;
(ii) increased energy security;
(iii) enhanced quality, sustainability, and operational maneuverability of the power supply;
(iv) growth in agricultural production and food processing resulting from a more stable supply of energy;
(v) increased food security and supply of raw materials;
(vi) creation of new jobs and reductions in local unemployment;
(vii) improved technical capacity for local developers and operators of SHPs;
(viii) maximum use of local resources and labor and minimal reliance on imports (one of the official goals of the government);[37] and
(ix) increased income and quality of life for the local population.

Barriers That Would Be Addressed by the Nationally Appropriate Mitigation Action

As mentioned above, several remaining gaps have slowed past government efforts to expand SHP capacity. Conducting a detailed analysis of these barriers and creating a road map to remove them would be among the NAMA's first activities. The study will define the scope, sequence, and substance of the next steps, as well as the entities and experts whose cooperation will be crucial. Some of the gaps to be examined are described briefly below.

[37] For small hydropower, the share of imported components (mainly equipment and controls) usually does not exceed 30% of total capital costs.

(i) **Institutional barriers.** Two agencies have been assigned to deal with hydropower generation: Uzbekenergo and Uzsuvenergo. There is no mechanism for coordinating their efforts to develop small hydropower or resolving situations where conflicting interests may arise. While Uzsuvenergo is focusing mainly on small hydropower, because of its significant potential for irrigation systems, Uzbekenergo is managing the whole power sector, including thermal plants, transmission and distribution, combined heat and power, and large hydropower. SHPs are only a tiny share of Uzbekenergo's overall responsibilities. Additionally, as the owner and operator of the national transmission grid, Uzbekenergo is the sole wholesale purchaser of power, through its subsidiary Energosotish. It controls the process of dispatch and load factors for any source connected to the grid through the National Dispatch Center. This situation creates uncertainty for potential investors in small hydropower projects not managed by Uzbekenergo.

(ii) **Legal barriers.** Article 10 of the Law on Electric Power Generation of 30 September 2009 stipulates that the state should own 100% of generation capacity for hydropower, which prevents private investment through traditional project finance.[38] There are no such restrictions for thermal power plants or electric network facilities. Additionally, there are no requirements for state ownership of power plants that use other renewable energy sources. In the absence of straightforward project financing, other forms of investment could be utilized, such as build-operate-transfer or design-build-finance-operate contracts, concessions, or production-sharing agreements. However, there is no experience with applying these instruments to power generation in Uzbekistan, and there is no supporting legal infrastructure. For example, the current Law on Production Sharing Agreements of 7 December 2001 only covers mining. This barrier should be addressed so that private capital can be involved in developing small hydropower.

(iii) **Economic barriers.** Both wholesale and retail tariffs for electric power in Uzbekistan are regulated under a set procedure (for example, by the Resolution of the Cabinet of Ministers 239 of 28 October 2010, Section IV). Calculations supporting wholesale ("inter-sectoral") and retail ("end-user") tariffs are performed and proposed by Uzbekenergo and submitted to the Ministry of Finance for approval. Inter-sector tariffs are different for each generating and transmission company. The system is complicated and nontransparent, and contains cross-subsidies. Moreover, the existing tariffs for hydropower generation do not fully cover the costs of production, operation, and maintenance of SHPs, nor do they enable new investment to be recouped. These barriers create a need to provide incentives for small hydropower through means such as dedicated tariffs, targeted tax breaks, or special incentives for importing the necessary equipment.

(iv) **Regulatory and operational barriers.** Uzbekenergo's monopoly on state-owned distribution and dispatch of generated electricity creates risk for investors—the risk that their SHPs will not be dispatched or placed under load even if the tariffs are favorable. Guarantees could be provided to investors, for example, through power purchase agreements with mandatory take or pay clauses. Alternatively, specific procedures for dispatch could be introduced that would be transparent and verifiable and would serve as a basis for business planning.

[38] Government of Kazakhstan. 2009. *Law on Power Generation N 3PY-225.* 30 September. Accessed at (in Russian) http://kkaetk.uz/index.php?id=podssylka-9&lang=ru

(v) **Financial barriers.** Given the scarcity of budget funds and competing demands for public finance, it is crucial for small hydropower projects to have access to credit and capital from domestic and foreign sources. Such access is limited, however. In addition to removing legal impediments (as described above), other steps to improve the investment climate and to ease access to capital are needed. They could include streamlining institutional steps and procedures for permits and providing specific guarantees to investors.

(vi) **Educational barriers.** Institutions involved in the development of small hydropower persistently note that they lack qualified, experienced staff—designers, project developers, managers, and operators. Most veteran specialists have left (due to natural attrition) and new specialists in the field are rare, as young staff choose more popular areas of the energy sector. The number of specialists needed is not huge, but the specialists will need to gain practice designing and operating modern facilities by working alongside the best experts.

(vii) **Informational barriers.** The new program for developing small hydropower needs to have a solid technical and informational component. A full-scale analysis of small hydropower potential was conducted in 1999 (within the first SHP program) by the design institute Vodoproject under the jurisdiction of the MAWR and other associated research and development institutions. This analysis, and the resulting suggestions for SHP construction, were discussed and approved by the Cabinet of Ministers. This analysis needs to be adjusted and updated, since many changes have occurred within the last 15 years in both anthropogenic factors (economic or technical) and natural factors (climatic or hydropower). There is also a need for a new atlas of small hydropower potential.

Investment Concept

The investment opportunity described in this concept note is part of the investment program proposed under the NAMA to accelerate the deployment of small-scale hydropower in Uzbekistan. Small-scale hydropower is defined as plants with installed capacity of less than 30 MW. The investment will provide technical and financial assistance for the construction of the Tuyabuguzskaya SHP which is under the jurisdiction of the MAWR and managed by Uzsuvenergo. The 12.5 MW new SHP will consist of two identical units with a generating capacity of 6.25 MW each.

The proposed Tuyabuguzskaya SHP falls under the jurisdiction of MAWR and has one of the highest priorities for Uzsuvenergo. Thus, it is almost guaranteed to be included in the final State Program for Development of Hydro Power for 2016–2020 to be finalized in 2015.

The requested investment will provide technical and financial assistance for the construction of the Tuyabuguzskaya SHP. The project will serve as a pilot study on how to address some of the barriers to be addressed in the NAMA and will help Uzsuvenergo's staff gain practical experience with planning and constructing small hydropower plants.

Technical Parameters

The proposed site for the SHP is the Tuyabuguz Water Reservoir in the Srednechirik region of Tashkent Oblast, 20 miles south of Tashkent.

The Tuyabuguzskaya SHP will be built according to the "below the dam" approach, i.e., the powerhouse will be constructed separately below the existing dam. The head of the dam is 26 meters while the nominal water flow is 55 cubic meters (m^3) per second. This allows for the construction of an SHP with installed capacity of 12.5 MW. The SHP will consist of two identical units with a generating capacity of 6.25 MW each.

The SHP will use the water released for irrigation near the Tuyabuguz Water Reservoir. As a result, the operation of the power plant will be determined by the needs of the irrigation system. The expected average load factor is 3,322 hours per year and the average annual power production is 41.8 million kWh.

The necessary construction and dam modification includes:

(i) water gate assembly,
(ii) penstock,
(iii) powerhouse,
(iv) water discharge channel,
(v) remote block with control equipment, and
(vi) connections to the distribution network.

Financial Parameters

The total cost of the project is estimated at $19.8 million, of which $9.84 million represents equipment costs.[39] Uzsuvenergo is considering a loan for 85% of this cost, which would be $16.8 million. Assuming Uzsuvenergo obtains financing on terms similar to other recent investments by ADB in Uzbekistan, it would be reasonable to assume a 15-year loan with a 5-year grace period and an interest rate of 3% or slightly above. This means a 4.31% effective interest rate after accounting for all necessary fees and financing expenses.

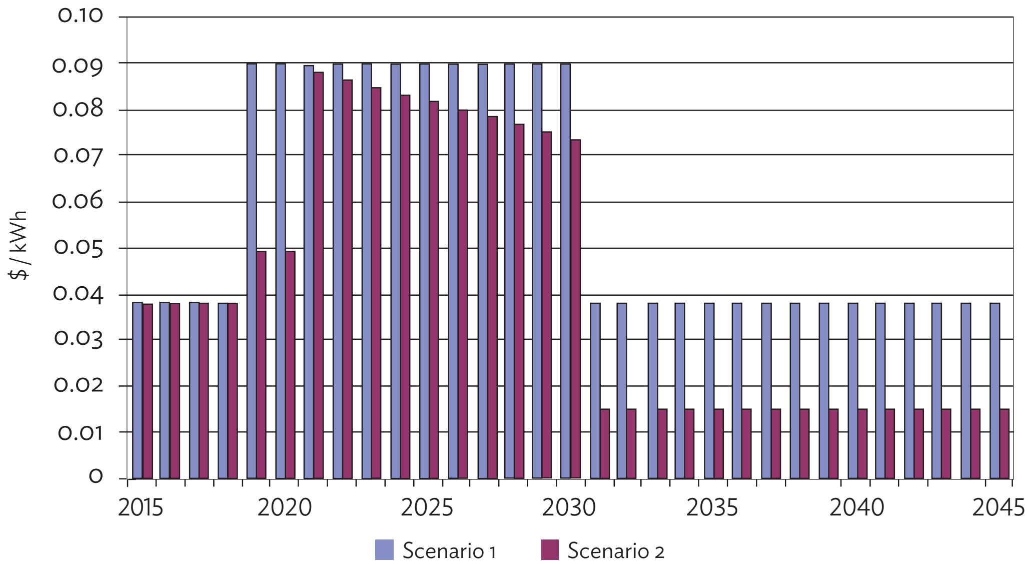
With the current electricity tariffs for Uzsuvenergo ($0.038) the project is not economically viable. At that tariff, the total revenue from electricity sales, without accounting for losses or any operating expenses, comes to $1.54 million while the repayment of principal alone (again, not accounting for interest and any other financing expenses) is $1.68 million. To make the project economically viable, some of the barriers to be addressed under the NAMA would have to be implemented. Most importantly, tariffs would need to be increased. This could be done for a fixed time period or during a loan repayment term (until 2030).

Scenario 1 in Figure 20 assumes a flat increase in tariffs to $0.09/kWh during 2018–2030. Under this scenario the loan can be repaid on schedule and the general project payback period becomes 12.5 years.

Scenario 2 in Figure 20 assumes the introduction of a levelized tariff which provides for cost recovery only. In this case, the long-term tariff after the loan is repaid can be set below the current level (to $0.015/kWh). However, in this scenario the tariff is still as high as in Scenario 1 in the early years and there is no profit from project implementation.

[39] Expressed as nominal cost.

Figure 20: Tariff Scenarios for the Tuyabuguzskaya Small Hydropower Plant



kWh = kilowatt hour.

Source: ADB. 2015a. *Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: Final Summary Report and Investment Concept Notes*. Consultant's report. Manila (TA 8119-REG).

Under Scenario 1 and a project lifetime of 30 years, the internal rate of return (IRR) of the Tuyabuguzskaya SHP becomes 11.86%. At a 10% discount rate, the net present value (NPV) is $0.675 million.

The cash flow of the project under Scenario 1 is shown in Figure 21.

Implementation Arrangements

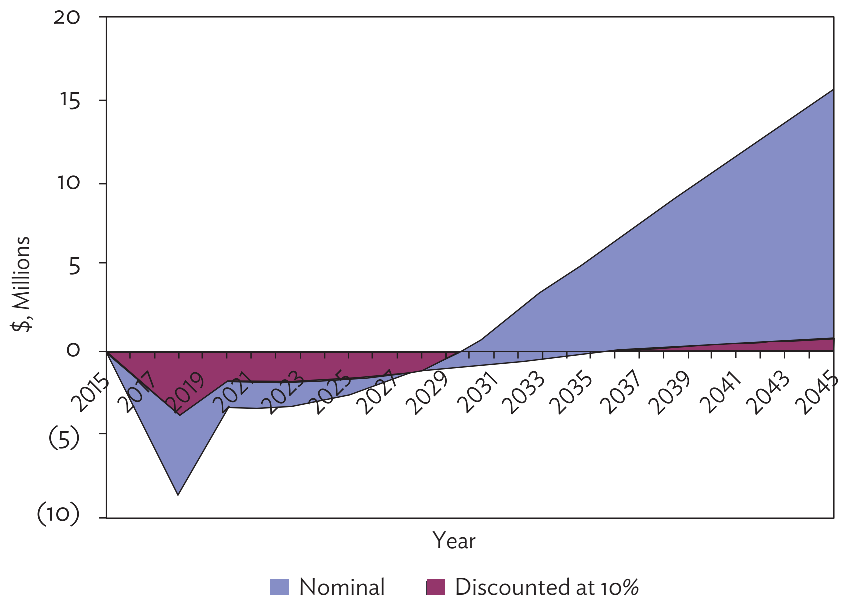
In the MAWR program to promote small hydropower, 2015 is selected as the first year of project implementation. However, assuming the earliest the loan disbursement and actual construction and installation work can start is 2016, the first year when the SHP would be connected to the grid and start selling electricity is 2019. With a 30-year project lifetime, the project would end in 2046.

Implementation of the project will be done by Uzsuvenergo, which will then operate the SHP. The final design adjustments and corrections will be undertaken by the design institute Hydroproject, which participated in the development of the Program of Small Hydropower Implementation.

Sensitivity Analysis

A simplified sensitivity analysis of the estimated cash flow for Tuyabuguzskaya SHP (using a one-factor-at-a-time method) indicates that any substantial adversarial change to the cost model can bring the project into red (Table 21). The most sensitive parameters are, naturally, the tariff

Figure 22: Cumulative Cash Flow Projection for Tuyabuguzskaya Small Hydropower Plant



Source: ADB. 2015a. *Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: Final Summary Report and Investment Concept Notes*. Consultant's report. Manila (TA 8119-REG).

Table 21: Sensitivity Analysis of the Tuyabuguzskaya Small Hydropower Plant Investment Opportunity

Parameter (Change by +- 10%)	Outcome Change		Sensitivity	
	IRR, %	NPV, $	IRR, %	NPV , %
Tariff	+3.914 or –3.677	+– 1,370,250	+–32	+–203
Total electricity production	+3.914 or –3.677	+– 1,370,250	+–32	+–203
Total investment cost	+4.032 or –3.202	+– 1,235,250	+–31	+–183
Interest rate	+– 0.712	+– 249,750	+–6	+–37
Profit tax	+– 0.356	+– 108,000	+2.5	+–16
Level of losses	+– 0.356	+– 67,500	+–1.5	+–8

IRR = internal rate of return, NPR = net present value.

Note: Assumes a 10% discount rate

Source: ADB. 2015. *Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan, and Uzbekistan: Options and Costs.* Consultant's report. Manila: ADB.

and total electricity production: change in either of them by +- 10% brings with it a +33% or -31% change in the project's IRR and a + -203% change in its NPV at a 10% discount rate.

The project is also very sensitive to the total investment cost, with a 10% change triggering a +34% or -27% change in the project IRR and a +-183% change in the NPV. Conversely, a 10% change in the profit tax or level of losses leads only to a 3% or 2% change in the IRR and a 16% or 10% change in the NPV respectively.

The project is much less sensitive to the loan terms, with a 10% change in the interest rate causing a 6% change in the IRR and a 37% change in NPV. Similar changes to the National Bank of Uzbekistan margin or unsecured guarantee fee have even less influence, creating only a 1.5% change in the IRR and 8% change in NPV; changes in time-limited or one-time fees like origination fee or commitment fee have almost no effect on the project economics.

These numbers indicate that modest measures such as offering minor tax discounts or providing a free state guarantee for investment loans will not have a real impact on the project's viability. Eliminating customs duties for imported equipment, on the other hand, can have an important positive effect, especially when the cost of equipment constitutes a substantial share of the total. This is likely the case when the SHP is built on existing hydro-technical infrastructure which does not require construction of a new dam, locks, or channels.

The risk of equipment cost overrun can be eliminated by conducting a careful design and all-inclusive feasibility study, holding wide and competitive tenders for suppliers, and signing a proper purchase agreement with the winner that would include comprehensive liquidated damage and warranty clauses. The risks of construction delays or cost overruns can be managed in a similar manner. Uzsuvenergo will have more control here since the construction work may be partially performed by in-house enterprises. The risks related to the changes in the tariffs are relatively transparent and predictable. The risk of changes to electricity production is the most difficult to manage, since this depends on the hydrological situation as well as the irrigation needs of the agricultural industry. If power generation at the Tuyabuguzskaya SHP is considered secondary to the irrigation function of the Tuyabuguz Water Reservoir, not much can be done to forestall these risks.

Cobenefits

The electricity generated by the Tuyabuguzskaya SHP will be connected to the national grid, and can be expected to increase the availability and reliability of local energy supplies.

The improved reliability of electricity supply will result in increased agricultural production, opportunity for expansion of small and medium enterprises, higher living standards through better infrastructure for schools, clinics, small businesses, local services for lighting and communication, and improved air quality. Other benefits include job creation during construction and operation of the SHP station, and secondary benefits from local economic activity.

Social and environmental benefits will accrue to the national economy, such as savings in natural gas use for electricity generation. Over the 30-year economic life, the Tuyabuguzskaya SHP would displace approximately 405 million cubic meters of natural gas. By displacing the use of natural gas for electricity generation, the Tuyabuguzskaya SHP will also result in estimated emission reductions of 22,238 tCO_2e per year. This estimate is based on multiplying the expected annual electricity generation from the Tuyabuguzskaya SHP (41.8 gigawatt hours) with the approved Clean Development Mechanism emission factor for Uzbekistan (532 tCO_2e per gigawatt hour).[40]

[40] United Nations Framework Convention on Climate Change, Clean Development Mechanism. 2013. ASB0003. Standardized Baseline: Grid Emission Factor for the Republic of Uzbekistan. Version 01.0 https://cdm.unfccc.int/methodologies/standard_base/Standardized_Baseline_PSB005_ver01.0.pdf

Conclusions and Recommendations

Annual emissions are small relative to global total, but are high on a per gross domestic product basis

Annual greenhouse gas (GHG) emissions of Azerbaijan, Kazakhstan, and Uzbekistan are a small (roughly 1%) contributor of global annual GHG emissions. However, this statistic masks the high intensity of GHG production in the three countries, whose GHG emissions per unit gross domestic product (GDP) is driven by reliance on fossil fuel resources and the legacy of Soviet infrastructure. In all three countries, more than 75% of the total 2010 GHG emissions were a result of activities in the energy and transport sectors. Energy-intensive industries are an important source of the GHG emissions in Kazakhstan and Uzbekistan, and fossil fuel production for export and domestic use contributes significant fugitive emissions in all three countries. In addition, the power sectors of Azerbaijan, Kazakhstan, and Uzbekistan are dominated by fossil fuel generation.

There is growing interest in stemming continued growth of national emissions

Increasing demand for carbon-intensive energy driven by population and income growth is expected to lead to a continued rise in GHG emissions through 2050. However, there is growing recognition in the three countries of the need and opportunity to re-examine resource options and growth strategies that aim for low-carbon growth. Cost-effective clean energy technologies and the promotion of energy efficiency, fuel switching, and low-carbon transport can play a crucial role in achieving increased development with low climate impacts. Each of the three countries has developed its own policies and targets in response to climate change.

Azerbaijan's efforts have thus far focused on identified renewable power targets, introduction of Euro-4 vehicle standards, and development of the State Program of Poverty Reduction. The government's Intended Nationally Determined Contribution (INDC) to the United Nations Framework Convention on Climate Change (UNFCCC) commits to a 35% reduction of total GHG emissions compared to the 1990 base level by 2030. This corresponds to a roughly 6% reduction from 2010 levels by 2030.

In its INDC, Kazakhstan committed to an unconditional 15% reduction (or 25% reduction conditional on additional finance and support) from 1990 levels by 2030. This corresponds to roughly 7% unconditional reduction and 18% reductions conditional on additional finance and support from 2010 levels by 2030.

As of February 2017, Uzbekistan has not submitted an INDC, but has focused on developing residential building efficiency standards, a solar road map, and a state program on hydropower development. The Uzbekistan government has delegated functions related to the UNFCCC and the Kyoto Protocol to Uzhydropowermet, who, in collaboration with the State Nature Protection Committee, has established a working group to prepare the country's INDC. The government prioritizes rehabilitation of existing plants and expansion of renewable energy, since they contribute to energy security and energy independence while also reducing emissions.

There is a significant potential in low-cost abatement options in the energy and transport sectors, however, further and potentially costlier abatement is likely required to meet INDC commitments

The analysis indicates that in each country, there is a selection of technical mitigation measures with high mitigation potential that can be accessed at either a direct cost savings or a very low cost per ton of abatement. Efficiency improvements in buildings and vehicles fall into this category across the three countries, and in some cases renewable energy options are also cost-effective.

For Azerbaijan, implementing all low-cost technical measures identified under the analysis can be done at a discounted cost of -$5 per ton of carbon dioxide equivalent (tCO_2e) and corresponds to a 10% reduction in emissions from the baseline level in 2050. The ensemble of all technical mitigation options would prevent emissions growth in the medium term, to around 2025 or 2030. However, under the modeled scenario, the analysis suggests that a further 15% reduction in emissions would still be required to meet Azerbaijan's INDC target of approximately 45 million tCO_2e ($MtCO_2e$) in 2030.

For Kazakhstan, implementing all low-cost technical measures identified under the analysis can be done at a discounted cost of $5 per tCO_2e and corresponds to a 15% reduction in emissions from the baseline level in 2030, and 13% reduction in 2050. However, under the modeled scenario, the analysis suggests that a further 15% reduction in emissions would still be required to meet Kazakhstan's unconditional INDC target of approximately 300 $MtCO_2e$ in 2030.

For Uzbekistan, implementing all low-cost technical measures identified under the analysis can be done at a discounted cost of -$33 per tCO_2e and corresponds to a 7% reduction in emissions from the baseline level in 2050. However, the impact of these measures are offset by the expected rapid economic and energy demand growth assumed in the No Action Scenario, and emissions are expected to rise relative to be higher than 2005 levels.

Nationally appropriate mitigation actions (NAMAs) can provide a framework for developing investment pipelines

NAMAs were conceptualized to be a national government initiative directed at transformational change within an economic sector or actions across sectors for a broader national focus. In support of sustainable development and designed to fit within a country's national development priorities, NAMAs can take different forms: sector plans; specific policies, regulations, and programs; or individual projects.

The NAMAs in this study were developed in consultation with government counterparts and grew out of consultations conducted during workshops and individual meetings with stakeholders in each country. Beyond their contributions to avoiding GHG emissions, the NAMAs were selected based on their alignment with national development priorities and the commitment and willingness of individual stakeholder agencies to engage in the NAMA process. The mitigation options selected for NAMAs were found to have no or very little cost per tCO_2e abated and are therefore attractive from the perspective of social benefits. The NAMA to foster use of natural gas for transport in Kazakhstan ($-82.6/$tCO_2e$) and the NAMA to accelerate small-scale hydropower in Uzbekistan ($-20.7/$tCO_2e$) both result in cost savings to society. The NAMA to promote agro-energy development based on renewable energy in Azerbaijan is low cost ($10/$tCO_2e$) and could result in important energy security and rural development benefits.

Appropriate policy, institutional development, and capacity building can help overcome barriers to investment in the proposed NAMAs

If Azerbaijan, Kazakhstan, and Uzbekistan choose to follow low carbon pathways, the potential scope for energy-related mitigation measures, including efficiency and fuel switching, appears to be significant. However, this study identified barriers that slow the adoption of mitigation options.

In Azerbaijan, large investment is needed in new renewable energy infrastructure, and existing incentives are insufficient to recover the initial high capital costs of renewable technologies. While the government recognizes and affirms the urgent need to expand generation of renewable energy, it has yet to advance policies to mandate the adoption of renewable energy. National experience with modern, highly efficient, and renewable energy-based technologies remain scarce; traditional approaches to rural development often do not recognize the potential for alternative and climate-friendly growth strategies. Restructuring tariffs for renewables, providing preferential loans, and creating a tax exemption for imported equipment will help address the financial, economic, and policy barriers by improving the tariff structure, increasing access to credit, and reducing the cost of equipment.

While the Kazakhstan government has explicitly stated its support for wider use of natural gas, economic and administrative barriers to their widespread adoption continue to exist. For instance, initial acceptance of the shift to natural gas will require compressed natural gas (CNG) support infrastructure and therefore a sufficiently large number of CNG end-users. Investment into this support infrastructure will be large, and existing rules and restrictions on budget procurement for every project component create administrative barriers, while the absence of national standards make new investment seem too risky. Coupled with the lack of information drives on the benefits of natural gas and national inexperience with the technology, initial adoption remains low.

Several remaining gaps have slowed past government efforts to expand small hydropower capacity in Uzbekistan. For instance, two agencies have been assigned to deal with hydropower generation—Uzbekenergo and Uzsuvenergo—although there is no mechanism for coordinating their efforts to develop small hydropower. New forms of investment could be utilized, such as build-operate-transfer or design-build-finance-operate contracts, concessions, or production-sharing agreements. However, there is no experience with applying these instruments to power generation in Uzbekistan, and there is no supporting legal infrastructure. The existing tariffs for hydropower generation do not fully cover the costs of production, operation, and maintenance of SHPs, nor do they enable new investment to be recouped. These barriers create a need to provide incentives for small hydropower through means such as dedicated tariffs, targeted tax breaks, or special incentives for importing the necessary equipment. Given the scarcity of budget funds and competing demands for public finance, it is crucial for small hydropower projects to have access to credit and capital from domestic and foreign sources. Such access is limited, however. In addition to removing legal impediments, other steps to improve the investment climate and to ease access to capital are needed. They could include streamlining institutional steps and procedures for permits and providing specific guarantees to investors.

Countries should seek to leverage private finance and the Green Climate Fund

Given the requirement for ambitious transformation needed to achieve their INDC targets, and redirect growth toward a low-carbon path, there is a need for each of the three countries to enable access to private finance by undertaking institutional and administrative reforms. Without private sector participation in financing, the government would have to act as the key investor. This could potentially limit the share of investment covered by national contributions. NAMAs are an ideal platform; they are designed to have a catalytic effect by including a mechanism for involving the private sector.

Furthermore, Azerbaijan, Kazakhstan, and Uzbekistan should leverage on support from the Green Climate Fund (GCF), which was created to support UNFCCC member countries in achieving their INDCs. The GCF has mechanisms for supporting projects, programs, and policies that are aimed at addressing climate change, by investing into low-emission and climate-resilient development.

Crisis into opportunity?

Global oil prices fell sharply in the second half of 2014; this situation persisted through 2015 and rose only marginally in 2016.[41] This was mirrored in similar falls in the cost of coal and gas. For Azerbaijan, Uzbekistan, and Kazakhstan, all three fossil fuel producers, this poses a dual challenge for their efforts to develop and invest in low-carbon energy and transport technologies. Reduced economic growth will lessen willingness to invest in projects with large up-front capital costs. Furthermore, lower fossil fuel costs effectively make low-cost alternatives less competitive. Damped economic growth may reduce annual GHG emissions for a period, but emissions growth is likely to continue post-recovery.

However, this situation can be leveraged into an opportunity for growth in other sectors. Lower fossil fuel prices could lead to a decline in cost of production, which may indirectly reduce

[41] J. Baffes et al. 2015. Understanding the Plunge in Oil Prices, Sources and Implications. In World Bank. *Global Economic Prospects: Having Fiscal Space and Using It.* Washington DC: World Bank. January.

inflation and support higher investment in other sectors.[42] Declining fossil fuel prices may have created an opportunity for productive reforms.[43] For example, governments can take advantage of the drop in the international oil price to remove costly fuel subsidy without suffering a spike in domestic fuel prices, and diverting resources to toward investments in infrastructure, including low-carbon technologies.

[42] G. Dominguez. 2014. How cheap oil can benefit Asia. *DW*. 18 December. Accessed at http://www.dw.com/en/how-cheap-oil-can-benefit-asia/a-18139318

[43] Footnote 41.

References

B. M. Al-Alawi and T. H. Bradley. 2013. Review of Hybrid, Plug-in Hybrid, and Electric Vehicle Market Modeling Studies. *Renewable and Sustainable Energy Reviews* 21. pp. 190–203.

F. Aliyev. 2015. Analysis of the Policy Reform Impact on Sustainable Energy Use in Buildings (Case Study in Azerbaijan). In United Nations Economic Commission for Europe. *Analysis of National Case Studies on Policy Reforms to Promote Energy Efficiency Investments*. New York and Geneva.

Argonne National Laboratory. Energy Systems. The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model Version 1.2.0.11312. https://greet.es.anl.gov/

Asian Development Bank. 2008. *AZE: Proposed Azerenergy Open Joint-Stock Company Power Transmission Enhancement Project*. Design and Monitoring Framework. Manila. Accessed at https://www.adb.org/sites/default/files/project-document/68100/42085-aze-dmf.pdf

———. 2010. *Climate Change in Central and West Asia: Routes to a More Secure, Low-Carbon Future*. Manila.

———. 2011. Kazakhstan Energy Efficiency Initiative RETA 6501-REG: Expanding the Implementation of the Energy Efficiency Initiative in Developing Member Countries. Technical Assistance report. Accessed at https://www.adb.org/projects/41279-012/main#project-documents

———. 2014a. *Economics of Climate Change in Central and West Asia - Mitigation Component: Inception Report*. Consultant's report. Manila (TA 8119-REG).

———. 2014b. *Economics of Climate Change in Central and West Asia - Mitigation Component: Interim Report*. Consultant's report. Manila (TA 8119-REG).

———. 2014c. *Key Indicators for Asia and the Pacific 2014, 45th Edition*. Manila.

———. 2014d. *Overview of LIBOR-based Loans: Sovereign and Sovereign-Guaranteed Borrowers.* Manila. January. http://www.adb.org/documents/overview-libor-based-loans-sovereign-and-sovereign-guaranteed-borrowers

———. 2014e. *Solar Energy Development: Economic and Financial Analysis.* Consultant's report. Manila (TA 8008–UZB).

———. 2014f. *Solar Energy Development: Roadmap to Solar Energy Development*. Consultant's report. Manila (TA 8008–UZB).

———. 2015a. *Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: Final Summary Report and Investment Concept Notes*. Consultant's report. Manila (TA 8119-REG).

———. 2015b. *Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: The Economics of Reducing Greenhouse Gas Emissions in the Energy and Transport Sectors*. Consultant's report. Manila (TA 8119-REG).

———. 2015c. *Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: Report on Nationally Appropriate Mitigation Actions*. Consultant's report. Manila (TA 8119-REG).

AzerEnerji. Energy Production. http://www.azerenerji.gov.az/index.php?option=com_content&view=article&id=91&Itemid=112&lang=en

Azernews News Agency. 2013. Network of CNG Fueling Stations to Be Opened in Uzbekistan This Year. 8 July. http://www.azernews.az/region/56443.html

J. Baffes et al. 2015. Understanding the Plunge in Oil Prices, Sources and Implications. In World Bank. *Global Economic Prospects: Having Fiscal Space and Using It*. Washington DC: World Bank. January.

S. C. Bhattacharyya. 2011. Integrated Analysis of Energy Systems. *Energy Economics: Concepts, Issues, Markets, and Governance*. pp. 393–416. Springer London. http://link.springer.com/chapter/10.1007/978-0-85729-268-1_17

Bibipedia. http://www.bibipedia.info

T. C. Bond et al. 2004. A Technology-Based Global Inventory of Black and Organic Carbon Emissions from Combustion. *Journal of Geophysical Research: Atmospheres.* 109. http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.168.4988&rep=rep1&type=pdf

BP. 2014. *BP Statistical Review of World Energy 2014*. http://www.bp.com/en/global/corporate/about-bp/energy-economics/statistical-review-of-world-energy/statistical-review-downloads.html

D. S. Bunch. 1993. "Demand for Clean-Fuel Vehicles in California: A Discrete-Choice Stated Preference Pilot Project." *Transportation Research Part A: Policy and Practice.* 27 (3). pp. 237–253. http://www.sciencedirect.com/science/article/pii/096585649390062P

E. D. Delarue, A. D. Ellerman, and W. D. D'haeseleer. 2009. Robust MACCs? The topography of abatement by fuel switching in the European power sector. *Energy*. 35 (3). pp. 1465–1475. http://www.sciencedirect.com/science/article/pii/S0360544209005234

Delphi Automotive. 2012. *Worldwide Emissions Standards: Passenger Cars and Light Duty Vehicles*. https://delphi.com/pdf/emissions/Delphi-Passenger-Car-Light-Duty-Truck-Emissions-Brochure-2012-2013.pdf

G. Dominguez. 2014. How cheap oil can benefit Asia. *DW*. 18 December. http://www.dw.com/en/how-cheap-oil-can-benefit-asia/a-18139318

E. A. Dzhaylaubekov. 2010. *Calculation and Analysis of Emissions of Harmful Pollutants from Motor Vehicles in the Ambient Air in the Republic of Kazakhstan*. KazATC.

———. 2014. Personal interview with ADB TA-8119 REG Team. 1 December. Astana, Kazakhstan.

O. Edenhofer, R. P. Madruga, and Y. Sokona, eds. 2012. *Renewable Energy Sources and Climate Change Mitigation: Special Report of the Intergovernmental Panel on Climate Change*. United Nations Environment Programme, World Meteorological Organization, Intergovernmental Panel on Climate Change, and Potsdam-Institut für Klimafolgenforschung. New York: Cambridge University Press.

Energy Charter Secretariat. 2013. *In-Depth Review of the Energy Efficiency Policy of Azerbaijan*.

Ergonomika. 2011. Отчет по энергоаудиту Объект: жилой многоквартирный дом. Адрес: г. Караганда ул. Мустафина 26.

European Union. 2015. *Final Report Summary - PROMITHEAS-4* (Knowledge transfer and research needs for preparing mitigation/adaptation policy portfolios). http://cordis.europa.eu/result/rcn/153387_en.html

European Commission Joint Research Centre. CO2 Time Series 1990-2013 per Region/country. http://edgar.jrc.ec.europa.eu/overview.php?v=CO2ts1990-2013

———. Emissions Database for Global Atmospheric Research. http://edgar.jrc.ec.europa.eu

———. GHG (CO_2, CH_4, N_2O, F-Gases) Emission Time Series 1990-2012 per Region/country. http://edgar.jrc.ec.europa.eu/overview.php?v=GHGts1990-2012

European Environment Agency. 2007. *EMEP/CORINAIR Emission Inventory Guidebook - 2007*. 16/2007. http://www.eea.europa.eu/publications/EMEPCORINAIR5

G. O. Ewing and E. Sarigöllü. 1998. Car Fuel-Type Choice under Travel Demand Management and Economic Incentives. *Transportation Research Part D: Transport and Environment.* 3 (6). pp. 429–44. doi:10.1016/S1361-9209(98)00019-4.

Food and Agriculture Organization of the United Nations Regional Office for Europe and Central Asia. 2012. *Assessment of the Agriculture and Rural Development Sectors in Eastern Partnership Countries: the Republic of Azerbaijan*. Budapest. http://www.fao.org/docrep/field/009/aq671e/aq671e.pdf

L. H. Goulder and A. R. Schein. 2013. Carbon Taxes versus Cap and Trade: A Critical Review. *Climate Change Economics.* 4 (3).

Government of Azerbaijan. 2008. *Order of the President of the Republic of Azerbaijan on State Program on Poverty Reduction and Sustainable Development in the Republic of Azerbaijan for 2008–2015.*

———. 2011. *Order of the President of Republic of Azerbaijan on Preparation of a National Strategy on the Use of Alternative and Renewable Energy Sources for 2010–2020*.

———. 2013. *Technology Needs Assessment for Climate Change Mitigation and Adaptation: Summary Report.*

———. 2014. *The First Biennial Updated Report of the Republic of Azerbaijan to the UN Framework Convention on Climate Change, Baku, 2014*. http://unfccc.int/resource/docs/natc/aze_bur1_eng.pdf

———. Ministry of Ecology and Natural Resources. 2012. *Technology Needs Assessment: Mitigation*.

———. 2013. National Forest Program (Forest Policy Statement and the Action Plan) 2015–2030.

———. 2014. Fugitive Emissions from Oil and Natural Gas.

Government of Azerbaijan, State Agency for Alternative and Renewable Energy Sources. 2014. *Strategic Plan (2015–2018)*. http://area.gov.az/strateji-plan-2015-2018/

———. 2015. List of Implemented Projects by ABEMDA for the Period 2011–2015 (ABEMDA_Cedvel).

Government of Azerbaijan, State Statistical Committee. 2014a. 1.4 Population Change. http://www.stat.gov.az/source/demoqraphy/indexen.php

———. 2014b. 1.9. Average Annual Prices (tariff) of Consumer Goods and Services Rendered to Population, in Manat. www.stat.gov.az/source/price_tarif/en/001_6en.xls

———. 2014c. 3.2 Turnover of Goods by Means of Transport, Million Tonne-Km. http://www.stat.gov.az/source/transport/indexen.php

———. 2014d. 5.1 Passenger Turnover in Transport Sectors, Million Passenger-Km. http://www.stat.gov.az/source/transport/indexen.php

———. 2014e. 10. Gross Domestic Product- Manats, Dollars, in Euro. www.stat.gov.az/source/system_nat_accounts/indexen.php

———. 2014f. 18.3 Number of Motor Vehicles. http://www.stat.gov.az/source/transport/indexen.php

———. 2014g. 18.4 Breakdown Passenger Cars by Type, Unit. http://www.stat.gov.az/source/transport/indexen.php

———. 2014h. Energy - Energy Balances. http://www.stat.gov.az/source/balance_fuel/indexen.php

———. 2015. Samukh. Environment and Other Indicators, the Regions. Baku. http://www.stat.gov.az/source/regions/az/004_7.xls

Government of Kazakhstan. 2003. *National Accounts of the Republic of Kazakhstan for 1996–2001, Statistical Yearbook*.

———. 2008. *National Accounts of the Republic of Kazakhstan for 2002–2006, Statistical Yearbook*.

———. 2009. Law on Power Generation GN ЗРУ-225. 30 September. http://kkaetk.uz/index.php?id=podssylka-9&lang=ru

———. 2009. The Rules Cost of Fuel and Lubricants and Maintenance Costs of Vehicles (Resolution № 1210).

———. 2012. *Transport in Kazakhstan 2007–2011, Statistical Yearbook*.

———. 2013a. *National Accounts of the Republic of Kazakhstan for 2007–2011, Statistical Yearbook*.

———. 2013b. *Resolution on Approval of the Action Plan for the Development of Alternative and Renewable Energy in Kazakhstan on 2013 - 2020 Years (Resolution № 43)*. 25 January. http://adilet.zan.kz/rus/docs/P1300000043

———. 2013c. *Resolution on Amending Resolution of the Government of the Republic of Kazakhstan dated December 29, 2007 № 1372 "On approval of the Technical Regulation on the requirements for emissions of harmful (polluting) substances of vehicles put into circulation in the territory of the Republic of Kazakhstan."* 6 February. http://adilet.zan.kz/rus/docs/P1300000097

———. 2013d. *Prices and Tariffs on Industrial Production Services in the Republic of Kazakhstan*.

———. 2013e. *Statistical Bulletin Housing and Communal Services of the Republic of Kazakhstan*.

———. 2013f. *Transport in the Republic of Kazakhstan, Statistical Yearbook 2013 Release*.

———. 2014a. *Decree of the President No. 725 on GOK Program of Development and Integration of Transport System in the Republic of Kazakhstan up to 2020*. 13 January. http://www.akorda.kz/upload/%D0%96%20%E2%84%96%20725%20%D1%80.pdf

———. 2014b. *Decree No. 969 on Amendments on adoption of Action Plan to implement Green Economy Concept 2013-2020, related to the Action Plan for switching vehicles to environmentally-friendly fuels, creation of associated infrastructures and introduction of electro mobiles*. 4 September. http://tengrinews.kz/zakon/docs?ngr=P1400000969

———. 2014c. Resolution of the Government of the Republic of Kazakhstan No. 724: On Approval of the Concept of Development of Fuel and Energy Complex of the Republic of Kazakhstan till 2030.

———. Administrative Police Committee of the Ministry of Internal Affairs. 2015. An Electronic Database Registration of Motor Vehicles in the Republic of Kazakhstan for 1990–2014.

———. Ministry of Environment and Water Resources. 2013. *III-IV National Communication of the Republic of Kazakhstan to the UN Framework Convention on Climate Change.*

———. Ministry of Environment and Water Resources. 2014. *National Inventory Report: Anthropogenic Emissions by Sources and Removals by Sinks of Greenhouse Gases Not Controlled by the Montreal Protocol for the 1990-2012 Years.* http://unfccc.int/national_reports/annex_i_ghg_inventories/national_inventories_submissions/items/8108.php

———. Ministry of Industry and New Technologies. 2014. *Draft Concept on Fuel and Energy Development to 2030 for Kazakhstan.*

———. Ministry of National Economy. 2014. Social and Economic Development of the Republic of Kazakhstan for 2015 - 2019, Minutes No. 37.

———. Ministry of National Economy, Committee on Statistics. The Official Statistical Information. http://www.stat.gov.kz/faces/wcnav_externalId/homeNationalAccountIntegrated?_afrLoop=422569088736733&_afrWindowMode=0&_afrWindowId=1a0gpmymwj_46#%40%3F_afrWindowId%3D1a0gpmymwj_46%26_afrLoop%3D422569088736733%26_afrWindowMode%3D0%26_adf.ctrl-state%3D1a0gpmymwj_62

———. Population. http://www.stat.gov.kz/faces/wcnav_externalId/homeNumbersPopulation?_adf.ctrl-state=4fddr6vu2_86&_afrLoop=72436109446300#%40%3F_afrLoop%3D72436109446300%26_adf.ctrl-state%3D72lpcfl3p_17

———. 2014. Transport in Kazakhstan 2009-2013, Statistical Yearbook.

Government of Kazakhstan, President of Kazakhstan. 2013. *Official text of the Green Economy Strategy and the Decree of the President No. 577 of 30 May 2013.* www.kazpravda.kz/_pdf/jun13/010613decree.pdf

———. 2014. Presidential Decree No. 725 dated 13 January 2014 (in Russian) www.mid.gov.kz/images/stories/contents/gp_150520141656.pdf

Government of Kazakhstan, Ministry of Regional Development. 2014. Concept of Reforming the District and City Heating Sector in the Republic of Kazakhstan.

Government of Russia, Ministry of Justice. n.d. *The Study of Motor Vehicles in Order to Determine the Cost of Repair and Evaluation (Guidelines for Forensic Experts).*

———. Ministry of Transport. 2008. Guidelines 'Application Rates of Fuels and Lubricants for Road Transport.' Annex to the Order of the Ministry of Transport of the Russian Federation of 14.03.2008 N AM-23-P.

Government of Uzbekistan, Centre of Hydrometeorological Service. 2008. *Second National Communication of the Republic of Uzbekistan under the United Nations Framework Convention on Climate Change*. http://unfccc.int/resource/docs/natc/uzbnc2e.pdf

———. President of Uzbekistan. 2009. Law of the Republic of Uzbekistan On Power Generation N ЗРУ-225 of 30 September 2009. http://kkaetk.uz/index.php?id=podssylka-9&lang=ru

———. 2015. Presidential Resolution 4707.

D. Greene, K.G. Duleep, and W. McManus. 2004. *Future Potential of Hybrid and Diesel Powertrains in the U.S. Light-Duty Vehicle Market.* Oak Ridge National Laboratory. http://cta.ornl.gov/cta/Publications/Reports/ORNL_TM_2004_181_HybridDiesel.pdf

J. T. Houghton et al., eds. 1996. *Climate Change 1995: The Science of Climate Change*. Intergovernmental Panel on Climate Change. Cambridge ; New York: Cambridge University Press.

International Fund for Agricultural Development. 2009. *Climate Change Impacts—Central Asia*.

Intergovernmental Panel on Climate Change. Intergovernmental Panel on Climate Change Database on Greenhouse Gas Emission Factors (IPCC-EFDB). http://www.ipcc-nggip.iges.or.jp/EFDB/main.php

International Carbon Action Partnership. 2016. *Kazakhstan Emissions Trading Scheme (KAZ ETS)*. https://icapcarbonaction.com/index.php?option=com_etsmap&task=export&format=pdf&layout=list&systems%5B%5D=46

International Energy Agency. IEA - Balance Definitions. http://www.iea.org/statistics/resources/balancedefinitions/#iproduction

———. Policies and Measures. Azerbaijan. Renewable Energy Target of Azerbaijan. http://www.iea.org/policiesandmeasures/pams/azerbaijan/name-36534-en.php

———. 2010. *Renewable Energy Essentials: Hydropower*. http://www.iea.org/publications/freepublications/publication/hydropower_essentials.pdf

———. 2012. *Energy Technology Perspectives 2012: Pathways to a Clean Energy System*. Paris: Organisation for Economic Co-operation and Development. http://www.oecd-ilibrary.org/content/book/energy_tech-2012-en

———. 2014a. *Key World Energy Statistics.* Paris. http://www.iea.org/publications/freepublications/publication/keyworld2014.pdf

———. 2014b. *World Energy Outlook 2014*. http://www.oecd-ilibrary.org/energy/world-energy-outlook-2014_weo-2014-en

International Monetary Fund. World Economic Outlook Database. http://www.imf.org/external/pubs/ft/weo/2014/02/weodata/index.aspx (accessed March 2016).

A. Jafarova. 2013. Uzbekistan Starts Construction of New Thermal Power Plant. *AzerNews*. 2 September. http://www.azernews.az/region/58852.html

JSC Uzbekenergo. 2010. Electric Power Industry of the Republic of Uzbekistan: A Current Situation and Development Prospects. http://www.jp-ca.org/navoiforum/materials/no.1/4uzbekenergo.pdf

———. On the Current State and Prospects for Energy Development. http://www.uzbekenergo.uz/en/activities/energy/

———. Investment Policy. http://www.uzbekenergo.uz/en/activities/investment-policy/

———. SJSC Uzbekenergo - Objects. http://www.uzbekenergo.uz/en/about/projects/

C. Kavalec. 1996. CALCARS: The California Conventional and Alternative Fuel Response Simulator. *A Nested Multinomial Vehicle Choice and Demand Model, Sacramento, CA: California Energy Commission*. http://listserver.energy.ca.gov/papers/CEC-999-1996-007.PDF

Y. Kaya, Yōichi and K. Yokobori, eds. 1997. *Environment, Energy, and Economy: Strategies for Sustainability*. Tokyo ; New York: United Nations University Press.

P. Kazakhstanskaya. 2015. "Green" path to economy growth. *Kazpravda*. 20 May 20. http://www.kazpravda.kz/interviews/view/zelenim-kursom-k-rostu-proizvodstva/

F. Kesicki and N. Strachan. 2011. Marginal abatement cost (MAC) curves: confronting theory and practice. *Environmental Science & Policy*. 14 (8). pp. 1195–1204. http://www.sciencedirect.com/science/article/pii/S1462901111001377

K. Konyrova. 2014. Kazakhstan Seeks a Greener Nation through Circular Economy. *The Astana Times*. 6 June. http://www.astanatimes.com/2014/06/kazakhstan-seeks-greener-nation-circular-economy/

D. H. Lee et al. 2013. Analysis on the Feedback Effect for the Diffusion of Innovative Technologies Focusing on the Green Car. *Technological Forecasting and Social Change.* 80 (3). pp. 498–509. doi:10.1016/j.techfore.2012.08.009.

J. Lee and Y. Cho. 2009. Demand Forecasting of Diesel Passenger Car Considering Consumer Preference and Government Regulation in South Korea. *Transportation Research Part A: Policy and Practice* 43 (4): 420–29. doi:10.1016/j.tra.2008.11.007.

Z. Lin and D. Greene. 2010. A Plug-in Hybrid Consumer Choice Model with Detailed Market Segmentation. https://www.researchgate.net/publication/254994821_A_Plug-in_Hybrid_Consumer_Choice_Model_with_Detailed_Market_Segmentation

U. Luterbacher et al. 2008. Glaciers and efficient water use in Central Asia. In B. Orlove, E. Wiegandt, and B. H. Luckman, eds. *Darkening Peaks: Glacier Retreat, Science, and Society*. Los Angeles, CA: University of California Press.

Mitsubishi Heavy Industries, Environmental & Chemical Engineering Co., Ltd., EX Research Institute Ltd., and Clean Association of TOKYO 23. 2014. *Study on Waste-to-Energy Project in Almaty, the Republic of Kazakhstan: Final Report.* http://www.jetro.go.jp/ext_images/jetro/activities/contribution/oda/model_study/energy_infra/pdf/h25_report02_en.pdf

C. Monsalve. 2013. *Controlling Greenhouse Gas Emissions Generated by the Transport Sector in ECA: Policy Options*. World Bank. http://siteresources.worldbank.org/INTTRANSPORT/Resources/336291-1227561426235/5611053-1229359963828/TP40-Final.pdf

G. M. Napolskikh. 1993. *Technological Design Motor Enterprises and Service Stations: Textbook for Universities*.

NGV Global. 2010. Joint Project Opens First CNG Fuel Station in Kazakhstan. 10 July. http://www.ngvglobal.com/blog/joint-project-opens-first-cng-fuel-station-in-kazakhstan-0720

Organisation for Economic Co-operation and Development. IEA Energy Prices and Taxes Statistics. http://dx.doi.org/10.1787/eneprice-data-en

———. 2010. *Projected Costs of Generating Electricity*. Paris: International Energy Agency, Nuclear Energy Agency, Organisation for Economic Co-operation and Development. http://public.eblib.com/choice/publicfullrecord.aspx?p=540186

President of Azerbaijan. Speech by Ilham Aliyev at the Opening of the Baku Plant for the Disposal of Solid Domestic Wastes. 19 December 2012. http://en.president.az/articles/6898

K. Ramazanov, E. Asadov, and A. Salimova. 2007. Report of Profitability of Electric Power Tariffs Varying During the Day in Azerbaijan. http://www.naruc.org/international/Documents/1B_Issues_Challenges_in_Azerbaijan_Energy_Sector_Chief_Advisor_Ramazanov_Eng.pdf

Review.uz. 2015. Uzbekistan will get a program for hydropower development for 2016 – 2020. 6 May. http://www.review.uz/index.php/novosti-main/item/2505-v-uzbekistane-poyavitsya-programma-razvitiya-gidroenergetiki-na-2016-2020-gody

Samruk-Green Energy. 2013. On Financing of the Construction Project in Kazakhstan, the First Major Wind Farm. 30 April. http://www.samruk-green.kz/en/press-relises/detail.php?ID=425

D. J. Santini and A.D. Vyas. 2005. Suggestions for a New Vehi*cle Choice Model Simulating Advanced Vehicles Introduction Decisions (AVID): Structure and Coefficients*. Argonne National Laboratory. https://www.anl.gov/energy-systems/publication/suggestions-new-vehicle-choice-model-simulating-advanced-vehicles

J. Sathaye and S. Meyers. 1995. Mitigation Assessment of the Energy Sector: An Overview. *Greenhouse Gas Mitigation Assessment: A Guidebook*. pp. 21–53. Springer. http://unfccc.int/resource/cd_roms/na1/mitigation/Resource_materials/Greenhouse_Gas_Mitigation_Assessment_Guidebook_1995/chap03.pdf

S. Schlömer et al. 2014. Annex III: Technology-Specific Cost and Performance Parameters. In O. Edenhofer et al., eds. *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

J. Shah et al. 2013. *Kazakhstan - Overview of climate change activities*. Washington DC: World Bank Group. http://documents.worldbank.org/curated/en/859941468040174046/Kazakhstan-Overview-of-climate-change-activities

Stockholm Environment Institute. 2012. Global Atmospheric Pollution Forum Emissions Inventory Workbook Template - Version 5.0. http://www.sei-international.org/gap-the-global-air-pollution-forum-emission-manual

———. 2014. LEAP 2014 User Guide. https://www.energycommunity.org/default.asp?action=userguide

———. 2015. Long-Range Energy Alternatives Planning System. https://www.energycommunity.org/default.asp?action=introduction

J. Struben and J. D. Sterman. 2008. Transition Challenges for Alternative Fuel Vehicle and Transportation Systems. *Environment and Planning B: Planning and Design.* 35 (6). pp. 1070–1097. doi:10.1068/b33022t.

Tariff (price) Council of Azerbaijan Republic. Resolutions. http://www.tariffcouncil.gov.az/?/en/resolution/archive/

Trend News Agency. 2012. Uzbekistan to Complete Project to Modernize Navoi TPP. http://en.trend.az/casia/uzbekistan/2056472.html

———. 2013. Uzbekenergo to Start Modernization of Tolimarjon TPP Worth $1.28 Billion. http://en.trend.az/casia/uzbekistan/2119380.html

United Nations Department of Economic and Social Affairs. 2012. World Population Prospects: The 2012 Revision. https://esa.un.org/unpd/wpp/publications/Files/WPP2012_HIGHLIGHTS.pdf

United Nations Development Programme. 2011a. Sustainable Land and Forest Management in the Greater Caucasus Landscape: Project Identification Form.

———. 2011b. Regional Climate Change Impacts Study for the South Caucasus Region.

———. 2014a. Nationally Appropriate Mitigation Actions (NAMAs) for Low-Carbon End-Use Sectors in Azerbaijan: UNDP Project Document. http://www.thegef.org/gef/sites/thegef.org/files/gef_prj_docs/GEFProjectDocuments/Climate%20Change/Azerbaijan%20-%20(5291)%20-%20Nationally%20Appropriate%20Mitigation%20Actions%20(NAMAs)/08-07-2014_ID5291_projdoc.pdf

———. 2014b. Promotion of Energy Efficient Urban Space Lighting. UNDP/GEF.

———. 2014c. Энергоэффективное Проектирование И Строительство Жилых Зданий: ОТЧЕТ ПО СТРОИТЕЛЬСТВУ ЭНЕРГОЭФФЕКТИВНОГО ДОМА В г.КАРАГАНДЕ (ул. ЕРМЕКОВА, МКР.9, БЛОК №5).

———. 2015. The Targets for Reduction of Energy Consumption/GHG Emissions in Key Sectors of the Economy of Uzbekistan. Tashkent, Uzbekistan.

United Nations Economic Commission for Europe. 2014. Consolidated Resolution on the Construction of Vehicles (R.E.3) Revision 3. http://www.unece.org/fileadmin/DAM /trans/main/wp29/wp29resolutions/ECE-TRANS-WP29-78-r3e.doc

United Nations Educational, Scientific and Cultural Organization. 2010. Use of Renewable Energy Sources in Central Asia. http://unesdoc.unesco.org/images/0018/001882/ 188236R.pdf

United Nations Framework Convention on Climate Change. 2015a. The NAMA Registry. http://unfccc.int/cooperation_support/nama/items/7476.php

———. 2015b. FOCUS: Mitigation - NAMAs, Nationally Appropriate Mitigation Actions. http:// unfccc.int/focus/mitigation/items/7172.php

United Nations Framework Convention on Climate Change Clean Development Mechanism Executive Board. 2012a. Project Design Document for UNFCCC CDM Project Baku Waste to Energy Project. https://cdm.unfccc.int/Projects/DB/RINA1349852899.64/view

———. 2012b. UNFCCC CDM Project Balakhani Landfill Project Appendix 1. https://cdm .unfccc.int/UserManagement/FileStorage/FU4VEYPK1D37ILAX2NZO59BW60HR8S

———. 2013. Project Design Document for UNFCCC CDM Project AzDRES Energy Efficiency Improvement. https://cdm.unfccc.int/Projects/DB/DNV-CUK1324273859.59/view

———. 2013b. ASB0003. Standardized Baseline: Grid Emission Factor for the Republic of Uzbekistan. Version 01.0. https://cdm.unfccc.int/methodologies/standard_base /Standardized_Baseline_PSB005_ver01.0.pdf

United States (US) Energy Information Administration. 2013a. Assumptions to the Annual Energy Outlook 2013: Transportation Demand. http://www.eia.gov/outlooks/aeo/ assumptions/pdf/0554(2013).pdf

———. 2013b. *Transportation Sector Demand Module of the National Energy Modeling System: Model Documentation*. http://www.eia.gov/forecasts/aeo/nems/documentation /transportation/pdf/m070%282013%29.pdf

———. 2013c. *Updated Capital Cost Estimates for Utility Scale Electricity Generating Plants*. http://www.eia.gov/forecasts/capitalcost/pdf/updated_capcost.pdf

———. 2014. International Energy Statistics. http://www.eia.gov/cfapps/ipdbproject /IEDIndex3.cfm

US Environmental Protection Agency. 2013a. *An Overview of Landfill Gas Energy in the United States.* https://www.epa.gov/lmop/overview-landfill-gas-energy-united-states

———. 2013b. *ArcelorMittal Coal Mines Karaganda Coal Basin, Kazakhstan: Pre-Feasibility Study for Coal Mine Methane Drainage and Utilization*. https://www.epa.gov/cmop/coal-mine-methane-kazakhstan

———. 2013c. Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 Through 2013. EPA-420-R-13-011. https://www.epa.gov/sites/production/files/2016-11/documents/420s16001.pdf

———. Web Factor Information Retrieval System (WebFIRE). http://epa.gov/ttn/chief/webfire/index.html

World Bank. World Development Indicators. http://data.worldbank.org/data-catalog/world-development-indicators

———. 2013a. Project Paper on a Proposed Additional Loan in the Amount of $220 Million and Restructuring of the Rail Trade and Transport Facilitation Project IBRD-75090. http://documents.worldbank.org/curated/en/109321468221973283/Azerbaijan-Additional-Financing-for-the-Rail-Trade-and-Transport-Facilitation-Project-restructuring

———. 2013b. Project Paper on a Proposed Additional Loan in the Amount of USD 47.1 Million and Restructuring to the Republic of Azerbaijan for the Integrated Solid Waste Management Project. 77434-AZ. http://www-wds.worldbank.org/external/default/WDSContentServer/WDSP/IB/2013/06/11/000445729_20130611104057/Rendered/PDF/774340PJPR0P14010Box377322B00OUO090.pdf

———. 2015a. Commodities Price Forecast. http://www.worldbank.org/content/dam/Worldbank/GEP/GEPcommodities/PriceForecast_20150422.pdf

World LP Gas Association. 2012. *Autogas Incentive Policies: A Country-by Country Analysis of Why and How Governments Promote Autogas and What Works*. http://www.worldlpgas.com/uploads/Modules/Publications/autogas-incentive-policies-2012-updated-july-2012.pdf

World Weather Online. 2015. Samarkand, Uzbekistan Weather Averages. http://www.worldweatheronline.com/Samarkand-weather-averages/Samarqand/UZ.aspx

President of Kazakhstan Concept for the Transition of the Republic of Kazakhstan to Green Economy." 2013. Astana: Republic of Kazakhstan. Available online: http://bit.ly/2cLbUer Accessed September 2016

Economics of Climate Change Mitigation in Central and West Asia

Ecological complexity and diverse ecosystems give Central and West Asia rich natural resources and hydrocarbon reserves. Countries in this region are exposed to climate change risks, and there is growing recognition that their carbon-intensive economies necessitate greenhouse gas mitigation. This report assesses the costs, benefits, and investment opportunities for greenhouse gas reduction in the energy and transport sectors of Azerbaijan, Kazakhstan, and Uzbekistan, and discusses indirect benefits of such reduction to human health and energy security. It gives policymakers, practitioners, and academics an overview of policy measures and technologies available for emission reduction, as well as scenarios of future emission trajectories in the three countries.

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