Technical Assistance Consultant's Report

Project Number: 44068-012
August 2015

Economics of Climate Change in Azerbaijan, Kazakhstan, and Uzbekistan: Final Summary Report and Investment Concept Notes

TA8119-REG Economics of Climate Change in Central and West Asia – Mitigation Component
(Financed by the Asian Clean Energy Fund under the Clean Energy Financing Partnership Facility)

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For the State Agency on Alternative and Renewable Energy Sources of the Republic of Azerbaijan, the Ministry of Energy of the Republic of Kazakhstan, and the Ministry of Finance of the Republic of Uzbekistan

Asian Development Bank

ABBREVIATIONS

AC	Alternating current
ADB	Asian Development Bank
AZN	Azerbaijan manat
CCNG	Combined cycle natural gas
CCS	Carbon capture and storage
CDM	Clean Development Mechanism
CFL	compact fluorescent lamp
CHP	Combined heat and power
CNG	Compressed natural gas
COP	Conference of Parties
CSP	Concentrated solar power
CO_2	Carbon dioxide
CO_2e	Carbon dioxide equivalent
DC	Direct current
ETS	Emission trading scheme
EU	European Union
GDP	Gross domestic product
GHG	Greenhouse gas
GWP	Global warming potential
HFCs	Hydrofluorocarbons
HPP	Hydropower plant
IEA	International Energy Agency
INDC	Intended Nationally Determined Contribution
IPCC	Intergovernmental Panel on Climate Change
IRR	Internal rate of return
KZT	Kazakhstan tenge
LEAP	Long-range Energy Alternatives Planning system
LED	Light-emitting diode
LNG	Liquefied natural gas
LPG	Liquefied petroleum gas
MARW	Ministry of Agriculture and Water Resources of the Republic of Uzbekistan
MRV	Monitoring, Reporting, and Verification
MSW	Municipal solid waste
NAMA	Nationally Appropriate Mitigation Action
NPV	Net present value
OECD	Organization for Economic Co-operation and Development
OFAT	One-Factor-at-a-Time
OM	Operating and maintenance
PPP	Purchasing power parity
PV	Photovoltaic
RETA	Regional Technical Assistance
SAARES	Azerbaijan State Agency for Alternative and Renewable Energy Sources
SHP	Small hydropower plant
SCNG	Single cycle natural gas
SOCAR	State Oil Company of Azerbaijan Republic
SEI	Stockholm Environment Institute
tCO_2e	Tonnes of carbon dioxide equivalent
T&D	Transmission and distribution

TOE	Tonne of oil equivalent
TPES	Total primary energy supply
TPP	Thermal power plant
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
USC	Ultrasupercritical
$	United States dollar
UZS	Uzbekistan som
WtE	Waste to energy

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I. EXECUTIVE SUMMARY

A. Introduction

1. The Asian Development Bank (ADB) designed *Regional Technical Assistance (RETA) 8119 Economics of Climate Change in Central and West Asia (the TA)* to increase the availability of information on the options and costs for reducing greenhouse gas (GHG) emissions (Mitigation Component) and reduce the negative effects of climate change (Adaptation Component) in Central and West Asia. This TA covers the Mitigation Component, which estimates the cost of reducing GHG emissions in the energy and transport sectors of Azerbaijan, Kazakhstan, and Uzbekistan. The Mitigation Component includes the following outputs:

> Output 1: The estimated cost of climate change mitigation in energy and transport in Azerbaijan, Kazakhstan, and Uzbekistan. The mitigation measures include the deployment of clean energy technologies and policy and measures needed for low carbon growth. The consultants gathered energy and transport emissions data from country workshops, regional workshops, and consultations with individual stakeholders. As part of Output 1, the consultants (i) developed the countries' GHG baselines and projections to 2050; (ii) identified GHG abatement options and targets with the use of marginal abatement cost curve analysis; (iii) identified gaps and needs in climate policies and plans; and (iv) quantified and monetized co-benefits of mitigation options. The results are presented in a regional report on the economics of reducing GHG emissions in the three target countries. The study was complemented by a two-year capacity development program to train decision makers in economic analysis of mitigation measures and systems for GHG measurement and reporting.
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> Output 2: Climate change mitigation investment opportunities in Azerbaijan, Kazakhstan, and Uzbekistan. The consultants developed four nationally appropriate mitigation action (NAMA) concepts, which are combined into a regional report on NAMAs. Output 2 also involved the formulation of investment concept notes that will support the implementation of individual project components of the NAMAs. The investment concept notes are attached with this Final Report.

B. Approach and Results

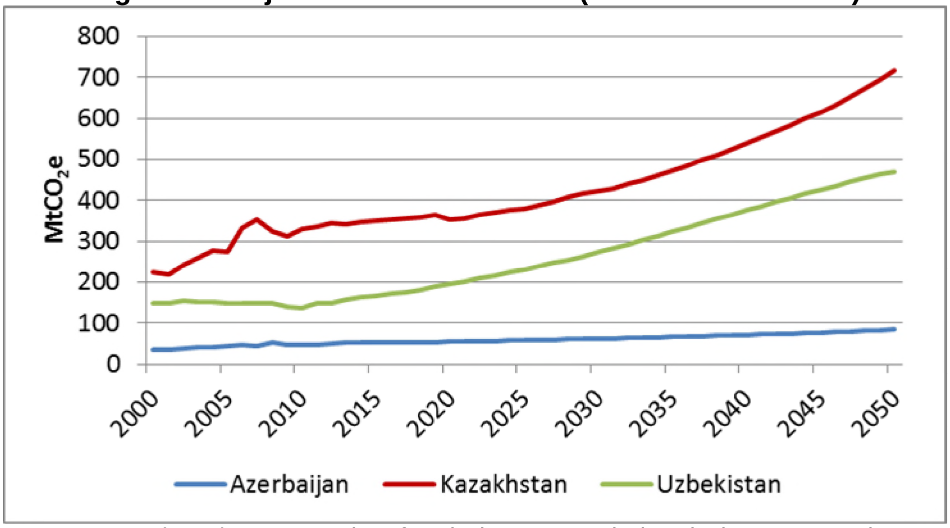
2. The consultants implemented this TA by conducting: (i) research and analysis for economic modeling, NAMA design, and investment analysis; (ii) consultations with stakeholders on mitigation priorities; and (iii) capacity development through training and workshops. Three national economic models were constructed using the Long-range Energy Alternatives Planning (LEAP) system.

3. The national model results indicate that increasing demand for carbon-intensive energy, driven by population and income growth, will lead to rising GHG emissions through 2050 in all three countries, particularly in Kazakhstan and Uzbekistan (Figure 1). As incomes rise and economic activity increases, people are buying more cars and building more houses, and enterprises are consuming more energy to meet the growing demand for products and services. If the energy and transport systems of Azerbaijan, Kazakhstan, and Uzbekistan remain as carbon-intensive as today, significant increases in GHG emissions will follow. But this situation also presents an opportunity: to re-examine resources and energy options and pursue green-growth strategies that enable increased development with lower climate impacts. The utilization of cost-effective clean energy technologies and the promotion of energy efficiency, fuel

switching, and low-carbon transport can play a crucial role in achieving these goals. Understanding the potential of such approaches will also support the region in leveraging public and private sector finance for prioritized mitigation options that contribute to national development goals.

4. Figure 1 shows the projected GHG emissions in Azerbaijan, Kazakhstan and Uzbekistan if no significant action is taken to reduce emissions beyond existing efforts to improve energy intensity and if countries continue to rely primarily on fossil fuels for energy and transport. Between 2010 and 2050, in this *no action* scenario, total projected emissions rise by 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 a growing potential to reduce fossil fuel–based emissions through efficiency, fuel switching, and other measures.

Figure 1: Projected GHG Emissions (No Action Scenario)



Source: ADB. Forthcoming. *Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs*, Manila.

5. All three countries are already evaluating and implementing measures to reduce GHG emissions. The consultants worked with national stakeholders to select priority mitigation actions for inclusion in the mitigation analysis, focusing on options that support national development priorities and for which data on costs and mitigation potential is available. Table 1 and Table 2 summarize the GHG abatement potential and cost for these mitigation options, sorted in order of increasing marginal abatement cost per tonne of carbon dioxide equivalent (tCO_2e). For comparison between countries, the final column on the right presents reduction costs in a common currency of 2010 $.

6. The mitigation options are organized according to three types of mitigation measures and are analyzed separately due to the potential overlap:

(1) Technical mitigation mini-scenarios which analyze one discrete physical or behavioral mitigation option or technology in comparison with the *no action* scenario, such as a change in technology deployment, differential resource management practices, or the attainment of a non-price target;

(2) Mitigation pricing mini scenarios which add one discrete price-based mitigation option to the *no action* scenario, such as a change in fuel or carbon prices; and
(3) Combined mitigation scenarios. These assume a portfolio of one or more of the technical mitigation mini-scenarios listed in the second bullet.

7. The technical mitigation options in Table 1 are analyzed according to the retrospective systems approach whereby the final abatement potential and cost per tonne for each option are calculated using the marginal emission reductions and costs incurred after the option was added to the prior mitigation option. Thus, the first option is evaluated in comparison to the *no action* scenario only, the second option in comparison to the *no action* scenario plus the first option, and so forth. This is done to account for interactions between mitigation options. The result is that mitigation options that are analyzed last show little or no additional abatement if the reductions are already captured under earlier overlapping mitigation options. For example, the mitigation option based on the State Agency for Alternative and Renewable Energy Sources (SAARES) Short-term Renewable Energy Plans in Azerbaijan is already captured under the Renewable Power Target. Therefore it does not result in additional emission reductions.

Table 1: Costs and Abatement Potentials for Technical Mitigation Mini-Scenarios in Azerbaijan, Kazakhstan, and Uzbekistan

Azerbaijan			
Scenario	**Cumulative Potential GHG Emission Reductions [a] [tCO_2e]**	**Reduction Cost per Tonne [2007 AZN / tCO_2e]**	**Reduction Cost per Tonne [2010 $ / tCO_2e]**
Euro 4 Vehicle Standards	12,301,298	-47.7	-70.2
SOCAR Eco-driving	1,926,241	-43.2	-63.6
Commercial CFL Lighting	44,199,773	-6.3	-9.3
Residential CFL Lighting	76,763,797	-5.8	-8.5
Forests 20% of Total Land Area	45,706,558	0.5	0.8
Forests 12.5% of Total Land Area	8,466,758	0.9	1.3
Improved Insulation	72,144,742	1.0	1.5
Small Hydro	33,939,169	1.3	1.9
Sustainable Land Management	12,052,454	2.2	3.3
Onshore Wind	15,534,982	5.8	8.5
Samukh Agro-Energy Complex	4,074,171	6.8	10.0
Renewable Power Target[1]	32,550,700	24.2	35.6
3 MW Small Solar	93,009	28.6	42.0
Municipal Solid Waste to Energy	4,751,891	56.5	83.1
Biogas	1,963,020	124.2	182.7
Electricity Network Upgrade	20,107,941	236.2	347.3
AC Rail Conversion	529,352	325.0	477.8
Solar Hot Water	1,416,631	379.5	558.0
Efficient Stoves	196,768	773.9	1,137.8

[1] The Renewable Power Target Scenario is 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.

Rail Electrification	91,026	909.4	1,337.1
SAARES Short-Term Plans	0	NA[b]	NA[b]
Kazakhstan			
Scenario	**Cumulative Potential GHG Emission Reductions [a] [tCO_2e]**	**Reduction Cost per Tonne [2010 KZT / tCO_2e]**	**Reduction Cost per Tonne [2010 $ / tCO_2e]**
CNG Fleet	27,295,626	-12,170.7	-82.6
CNG Passenger Cars	1,453,274	-2,786.3	-18.9
Improved Heat Pipe Insulation	166,006,789	-292.3	-2.0
Coalbed Methane Capture	94,167,987	-139.5	-0.9
Efficient New Homes	238,762,921	-43.4	-0.3
Natural Gas Power Target (Green Growth)	399,039,208	337.0	2.3
Internal Heating Network Improvements	404,198,552	507.4	3.4
CO_2 Cap on Power (Green Growth)	673,820,538	558.4	3.8
Improved Insulation	395,591,779	1,007.6	6.8
Advanced Windows	77,757,249	1,808.7	12.3
Heat Distribution Upgrades	159,352,071	2,877.4	19.5
Alternative Power Target	217,505,879	4,457.0	30.2
Expanded + Optimistic Nuclear Power[2]	38,826,060	4,771.7	32.4
Rehabilitation of National Grid	21,979,657	13,991.4	95.0
Urban LED Lighting	459,737	19,499.8	132.3
Waste to Energy	-142,956	NA[b]	NA[b]
Euro 5 Vehicles	-10,237,033	NA[b]	NA[b]
Early Vehicle Retirement	-31,179,955	NA[b]	NA[b]
Uzbekistan			
Scenario	**Cumulative Potential GHG Emission Reductions [a] [tCO_2e]**	**Reduction Cost per Tonne [2013 UZS / tCO_2e]**	**Reduction Cost per Tonne [2010 $ / tCO_2e]**
Residential Building Efficiency	569,147,765	-111,064.7	-44.9
Large Hydro	110,835,506	-100,493.5	-40.7
Small Hydro	22,924,927	-51,184.7	-20.7
Residential Renewable Energy	26,166,554	-24,043.9	-9.7
Alternative Vehicles	128,471,751	1,546.2	0.6
Heat Network Improvements	48,112,419	19,898.4	8.1
Heat Plant Efficiency	71,424,254	45,803.2	18.5
Solar Photovoltaic	31,200,307	60,451.5	24.5
Electricity Grid Improvements	57,640,715	223,258.6	90.3
Rail Electrification	3,737,049	3,107,406.1	1,257.3

[a] The analysis of potential GHG emission reductions is expressed in 100-year global warming potentials (GWP).
[b] Scenarios marked “NA” have undefined abatement costs since they result in increased or unchanged emissions. In some cases (e.g., the Renewable Power Target scenario in Azerbaijan), this result is due to interactions with scenarios ranked higher in the retrospective systems order.

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

Source: ADB. Forthcoming. *Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs.* Manila: ADB.

Table 2: Costs and Abatement Potentials for Pricing and Combined Mitigation Scenarios in Azerbaijan, Kazakhstan, and Uzbekistan

Azerbaijan				
Scenario	**Cumulative Potential GHG Emission Reductions [a] [tCO_2e]**	**Percent Change by 2050 Compared to *No Action* Scenario (%)**	**Reduction Cost per Tonne [2007 AZN / tCO_2e]**	**Reduction Cost per Tonne [2010 $ / tCO_2e]**
Carbon Tax (Low)	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	575,454,155	-19.1	5.0	7.4
OECD Fuel Prices	1,103,806,342	-36.6	5.2	7.7
State Program of Poverty Reduction	-479,774,029	15.9	NA[b]	NA[b]
All Low-Cost Technical Measures	327,109,943	-10.8	-3.4	-4.9
All Moderate-Cost Technical Measures	359,753,652	-11.9	-0.9	-1.3
All Technical Measures	388,810,279	-12.9	15.2	22.3
Kazakhstan				
Scenario	**Cumulative Potential GHG Emission Reductions [a] [tCO_2e]**	**Percent Change by 2050 Compared to *No Action* Scenario (%)**	**Reduction Cost per Tonne [2010 KZT / tCO_2e]**	**Reduction Cost per Tonne [2010 $ / tCO_2e]**
Emissions Trading Scheme	1,544,370,058	-7.1	638.7	4.3
OECD Fuel Prices	1,124,925,667	-5.2	3,090.1	21.0
Extended ETS	1,558,672,146	-7.2	11,904.8	80.8
All Low-Cost Technical Measures	2,777,194,623	-12.9	768.4	5.2
All Technical Measures	2,916,074,370	-13.5	956.0	6.5
Uzbekistan				
Scenario	**Cumulative Potential GHG Emission Reductions [a] [tCO_2e]**	**Percent Change by 2050 Compared to *No Action* Scenario (%)**	**Reduction Cost per Tonne [2013 UZS / tCO_2e]**	**Reduction Cost per Tonne [2010 $ / tCO_2e]**
All Low-Cost Technical Measures	905,658,923	-6.5	-82,809.3	-33.5
All Technical Measures	1,069,661,249	-7.7	-42,404.2	-17.2

[a] The analysis of potential GHG emission reductions is expressed in 100-year global warming potentials (GWP).
[b] Scenarios marked "NA" have undefined abatement costs since they result in increased or unchanged emissions.
Source: ADB. Forthcoming. *Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs.* Manila: ADB.

8. The analysis indicates that, in each country, a selection of technical measures with high mitigation potential can be implemented at either a direct cost savings or at a very low cost per tonne of abatement. These include switching to low-carbon fuels for transport, various energy efficiency measures, and increased use of hydropower in all three countries. Similarly, pricing

scenarios, such as a carbon tax in Azerbaijan and emission trading in Kazakhstan can result in considerable reductions at a cost of less than $ 5 per tonne of CO_2e abated.

9. Many of the highest-cost measures contribute relatively little to the overall level of abatement that is achievable by the ensemble of mitigation options. However, some options with a high cost per tonne may still be worth considering if they advance other social goals such as economic development, lower air pollution, or increased energy security. The TA quantified several potential co-benefits which may increase the attractiveness of mitigation.

10. Under the TA, four different NAMA concepts were also developed to meet the basic criteria agreed to during the sixteenth session of the Conference of the Parties (COP 16) to the UNFCCC held in Cancun, Mexico in 2010:

(i) They are nationally appropriate mitigation actions implemented within a sustainable development context;
(ii) They can be supported by technology transfer, financing or capacity building;
(iii) They contribute to reducing GHG emissions relative to business-as-usual in 2020; and
(iv) The mitigation actions are measurable, reportable, and verifiable.

11. Finally, three climate change mitigation investment concept notes were developed as part of the TA. The investment concepts are tied to the NAMAs and are designed to support the implementation of a specific component of the individual NAMAs.

12. Azerbaijan's NAMA and investment concept notes focus on renewable energy development in the agriculture sector, Kazakhstan proposed NAMAs for promoting natural gas in transport and energy efficiency in all sectors, and Uzbekistan designed a NAMA to promote investment in small-scale hydro. The NAMA concepts developed under this TA are ready for submission to the United Nations Framework Convention on Climate Change (UNFCCC) NAMA Registry,[3] the public online platform that facilitates matchmaking between planned NAMAs and funding sources. The Registry also serves as a venue for countries to get recognition for their mitigation efforts.

13. The capacity development program under the TA strengthened the ability of national experts to assess the costs and benefits of mitigation, design effective NAMAs and investment proposals, and measure the GHG and other impacts of mitigation actions once implemented. The program included national and regional trainings on conducting cost–benefit analysis of mitigation in the energy and transport sectors, using practical examples from the national LEAP models developed under the TA. It also included trainings on NAMA design, GHG emissions accounting, and measuring and monitoring of the results of mitigation actions. Altogether, 254 national decision makers have been trained during three regional and seven national workshops. Of these, 89 (or 35%) were women.

C. Summary and Recommendations

14. The economic analysis under the TA suggests that without significant intervention Azerbaijan, Kazakhstan and Uzbekistan will continue to rely primarily on fossil fuels for energy supply. This in turn will lead to a continued rise in GHG emissions through 2050 due to the expected economic and population growth, offsetting expected improvements in energy and GHG intensity. However, the TA report *Economics of GHG Emissions in the Energy and*

[3] The NAMA Registry. 2015. http://unfccc.int/cooperation_support/nama/items/7476.php

Transport Sectors of Azerbaijan, Kazakhstan, and Uzbekistan identified a number of cost-effective, nationally appropriate mitigation options available to the three countries that will help them begin to move away from a predominantly fossil fuel-based economy. These are described in Section III.B of this report. Section III.B.4 discusses several important co-benefits which can further improve the attractiveness of these mitigation measures.

15. When combined into packages, the mitigation options included in this study have an appreciable effect on projected GHG emissions through 2030. However, they will not be able to prevent a significant increase in GHG emissions in the long run. As discussed in Section III.B.7, slowing the increase in long-run emissions (i.e., 2030-2050) will require additional measures such as targeting energy use for buildings, industry, and transport, and pushing efficiency further than currently modeled. Additional reduction could be achieved by switching to low-carbon transport options such as electric rail and cars, hydrogen, and in some cases biofuels; introduction of a meaningful carbon price; and integrated land use planning in urban areas to reduce vehicle and passenger miles. Additional de-carbonization of the power sector would also likely be necessary. Such pathways will be more costly, however, and may only be feasible if supporting international finance and technical cooperation is available.

16. Building up institutional capacity and strengthening expertise on accessing financial support for these mitigation measures is crucial for Azerbaijan, Kazakhstan, and Uzbekistan. As described in the *Report on Nationally Appropriate Mitigation Actions (NAMAs) in Azerbaijan, Kazakhstan, and Uzbekistan*,[4] the climate finance community is emphasizing the need for measuring, monitoring, and verifying that the resources provided are producing real and transformative GHG emission reductions. As a result, the three study countries will need to establish clear frameworks and procedures for tracking emissions, their co-benefits, and the requested climate finance. The NAMA report provides a status update on the institutional arrangements for NAMAs in each country.

17. Preparing quantified assessments of future GHG emission trajectories and potential emission reduction pathways are both increasingly important, as reflected by the international guidance on preparing Intended Nationally Determined Contributions (INDCs) ahead of the Conference of Parties (COP 21) to the UNFCCC in Paris in December 2015. The governments of Azerbaijan, Kazakhstan, and Uzbekistan must continue to build on national GHG modeling efforts, such the one conducted through the TA.

18. Given the need to work across traditional sectors and line ministries in order to implement truly transformative mitigation actions and NAMAs, countries will benefit from introducing inter-agency committees and/or other institutions for coordinating such efforts. As proposed in the *Report on Nationally Appropriate Mitigation Actions (NAMAs) in Azerbaijan, Kazakhstan, and Uzbekistan*, these could be modeled after the countries' institutional arrangements for the Clean Development Mechanism (CDM) and Joint Implementation (JI), which have effectively promoted collaboration across many agencies.

19. Finally, to attract international climate finance, each of the three countries needs to develop its own domestic financial institutions to access and leverage climate funds. This includes providing domestic resources for clean energy and transport measures.

[4] ADB. *Report on Nationally Appropriate Mitigation Actions (NAMAs) in Azerbaijan, Kazakhstan, and Uzbekistan.* Manila. August 2015.

II. INTRODUCTION AND BACKGROUND

A. Project Background and Objectives

20. The Asian Development Bank (ADB) plays a key role in assisting Central and West Asian countries move toward low-carbon growth. As part of this support, the ADB designed the *Regional Technical Assistance (RETA) 8119 Economics of Climate Change in Central and West Asia (the TA)* to increase the availability of information on the options and costs for reducing greenhouse gas (GHG) emissions (Mitigation Component) and reduce the negative effects of climate change (Adaptation Component) in Central and West Asia. This TA covers the Mitigation Component which estimates the cost of reducing greenhouse gas emissions in the energy and transport sectors of Azerbaijan, Kazakhstan, and Uzbekistan. Access to this information will support the three countries in leveraging increased public and private sector finance to address prioritized mitigation actions. The TA was approved by the ADB board in July 2012 and is co-financed by the Asian Clean Energy Fund under the Clean Energy Financing Partnership Facility and the Climate Change Fund. The Mitigation Component of the TA started in May 2013 and will be completed in August 2015.

21. The Mitigation Component includes the following outputs:

> Output 1: The estimated cost of climate change mitigation in energy and transport in Azerbaijan, Kazakhstan, and Uzbekistan. The mitigation measures include the deployment of clean energy technologies and policy and measures needed for low carbon growth. The consultants gathered energy and transport emissions data from country workshops, regional workshops, and consultations with individual stakeholders. As part of Output 1, the consultants (i) developed the countries' GHG baselines and projections to 2050; (ii) identified GHG abatement options and targets with the use of marginal abatement cost curve analysis; (iii) identified gaps and needs in climate policies and plans; and (iv) quantified and monetized co-benefits of mitigation options. The results are presented in a regional report on the economics of reducing GHG emissions in the three target countries. The study was complemented by a two-year capacity development program to train decision makers in economic analysis of mitigation measures and systems for GHG measurement and reporting.
>
> Output 2: Climate change mitigation investment opportunities in Azerbaijan, Kazakhstan, and Uzbekistan. The consultants developed four nationally appropriate mitigation action (NAMA) concepts, which are combined into a regional report on NAMAs. Output 2 also involved the formulation of investment concept notes that will support the implementation of individual project components of the NAMAs. The investment concept notes are attached with this Final Report.

22. The expected impact of the TA is the implementation of climate change mitigation actions and measures in Azerbaijan, Kazakhstan, and Uzbekistan. The outcome is a better understanding of the cost of climate change in these countries. The Design and Monitoring Framework is presented in Appendix 1.

B. Conduct of the Study

1. Approach

23. To assess the costs and benefits of mitigation under Output 1, the consultants developed three national economic models—one for each of the study countries—based on national data and development priorities. Stakeholders in Azerbaijan, Kazakhstan, and Uzbekistan requested this approach to reflect the pronounced differences in the availability and quality of input data, the structure of the energy and transport systems, and the mitigation strategies in each country. The three models are described in more detail in the TA report *Economics of GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan, and Uzbekistan.*[5]

24. The consultant team used the economic models to assess the direct costs and benefits of a range of mitigation options and emission scenarios in each country and develop marginal abatement cost curves (MACCs), which illustrate the potential for and cost of GHG abatement if all the mitigation options are implemented. The direct costs and benefits examined include capital, operating and maintenance, fuel, and other implementation costs. These are *social* costs and benefits, and therefore do not consider the distributional impacts of *who* pays for them. The consultants also used the model outputs to quantify potential indirect benefits (i.e., co-benefits) of mitigation. The co-benefits analyzed for the TA include reduced emissions of air pollutants, health benefits of reduced air pollution, fuel savings, and increased energy security.

25. At the completion of the TA, the three models, including the data and assumptions used, will be turned over to the national counterparts. They will also be posted on ADB's website, thereby making it easier for relevant stakeholders to update the models in the future.

26. In support of Output 2, the consultants developed four different NAMA concepts, reflecting different country priorities and mitigation strategies. These are summarized in Table 3 and the TA report on *Nationally Appropriate Mitigation Actions (NAMAs) in Azerbaijan, Kazakhstan, and Uzbekistan*.[6] NAMAs are voluntary mitigation actions implemented by developing countries in the context of sustainable development. They are designed to change emission trends in developing countries and offer countries an opportunity to be recognized for domestic mitigation measures or seek international support for their implementation. 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.[7] Azerbaijan's NAMA focuses on renewable energy development in the agriculture sector, Kazakhstan's proposed NAMAs promote natural gas in transport and energy efficiency in all sectors, and Uzbekistan's NAMA encourages investment in small-scale hydropower.

27. The NAMA concepts developed under this TA are ready for submission to the United Nations Framework Convention on Climate Change (UNFCCC) NAMA Registry,[8] the public online platform that facilitates matchmaking between planned NAMAs and funding sources. The Registry also serves as a venue for countries to get recognition for their mitigation efforts.

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[5] ADB. Forthcoming. *Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs*, Manila.
[6] ADB. *Report on Nationally Appropriate Mitigation Actions (NAMAs) in Azerbaijan, Kazakhstan, and Uzbekistan.* Manila. August 2015.
[7] UNFCCC. *FOCUS: Mitigation - NAMAs, Nationally Appropriate Mitigation Actions.* http://unfccc.int/focus/mitigation/items/7172.php
[8] The NAMA Registry. 2015. http://unfccc.int/cooperation_support/nama/items/7476.php

Table 3: Proposed NAMAs and Investment Concept Notes

	Azerbaijan	Kazakhstan	Uzbekistan
NAMA Concepts	Promoting agro-energy development based on renewable energy	Fostering use of natural gas in the transport sector Developing a national energy efficiency support system	Accelerating deployment of small-scale hydropower
Investment Concept Notes	Construction of solar photovoltaic and biogas plants at the Samukh Agro-Energy Residential Complex	Construction of a network of 10 compressed natural gas refueling stations	Construction of the Tuyabuguzskaya small hydropower plant

Source: ADB. *Report on Nationally Appropriate Mitigation Actions (NAMAs) in Azerbaijan, Kazakhstan, and Uzbekistan.* Manila. August 2015.

28. The TA also prepared three climate change mitigation investment concept notes. These concepts, which are listed in Table 3, are designed to support the implementation of a specific component of the individual NAMA concepts.

29. The TA combined the economic analysis and NAMA development with a two-year capacity development program. The program included national and regional trainings on conducting cost-benefit analysis of mitigation in the energy and transport sectors. It also included trainings on NAMA design, GHG emissions accounting, and measuring and monitoring of the results of mitigation actions.

2. Methodology

30. The design and implementation of TA Outputs 1 and 2 involved ongoing stakeholder input to ensure that nationally appropriate mitigation measures were incorporated into the economic analysis and the resulting NAMAs and investment concepts. The consultant team implemented the TA through a combination of: (i) consultations with stakeholders during workshops and individual meetings to identify mitigation priorities and confirm assumptions for the economic analysis and NAMA design, (ii) research and analysis of data for economic modeling, NAMA design, and investment analysis, and (iii) capacity development through training and workshops.

a. Output 1

31. To help ensure the long-term sustainability of the tools and knowledge resulting from the economic analysis conducted under Output 1, the three national-scale economic models were developed in the Long-range Energy Alternatives Planning (LEAP) system, a widely-used and highly flexible software tool for integrated energy and transport policy analysis and climate change mitigation assessments developed by SEI (SEI, 2015). Key features of the tool include support for constructing different scenarios within a model, an annual time step for input data and results, and support for multiple modeling methodologies within an energy and transport accounting framework (Bhattacharyya, 2011). A key benefit of LEAP is its low initial data requirements, which is useful when working in countries with limited data availability. Owing to the flexibility, user friendliness, and low cost LEAP is often the preferred option for national and regional mitigation cost-benefit analyses and the UNFCCC recommends its use for analyzing GHG emission scenarios to prepare national communications on climate change to UNFCCC.[9] Thousands of organizations in 190 countries worldwide have used LEAP, including many in transition economies. The LEAP system is provided to developing country governments and

[9] Abt Associates, 2014b. *RDTA–8119 REG: Economics of Climate Change in Central and West Asia—Mitigation Consultant. Inception Report*. Bethesda, 2014.

academic institutions free of charge, making it easier for stakeholders to continue to use the national models after the TA's completion.

32. At the TA's inception, the European Commission was working with LEAP in Kazakhstan and Azerbaijan to support the development of climate mitigation scenarios and policy portfolios for mitigation and adaptation planning,[10] and Uzhydromet in Uzbekistan had independently started using LEAP for preparation of the country's national communications to the UNFCCC. Stakeholders in all three countries indicated strong interest in receiving extensive training on the use of LEAP to build up internal government capacity for its use.[11]

33. The analysis of co-benefits was done separately from the national LEAP models, using quantitative outputs from the models, such as changes in air pollutants, renewable energy generation, and energy consumption by fuel type. To analyze the human health co-benefits of reduced air pollution concentrations, the consultants developed a spreadsheet model for linking air pollution concentrations to human mortality and for monetizing the value of avoiding these mortalities. The approach is documented in the *Interim Report* for the TA.[12]

b. Output 2

34. The selection of the four NAMA concepts for this TA grew out of stakeholder consultations and was supported by the Output 1 economic analysis of mitigation options, which identified the most cost-effective mitigation options in each country. The selected concepts aligned with national development priorities, and the individual stakeholder agencies demonstrated their commitment and willingness to engage in the NAMA process and provide the information needed for NAMA development.

35. Similarly, stakeholder consultations and feedback guided the selection of the three investment concepts. In this case, stakeholders prioritized project activities within each NAMA which will require financial assistance from other sources than the national budget in order to be implemented.

c. Capacity Development Program

36. The TA was complemented by capacity development to help stakeholders develop the necessary skills to use the models and implement the NAMAs and investment concepts upon completion of the TA. The capacity development involved several national and regional training workshops held throughout the course of the TA. These focused on strengthening the ability of national experts to: (i) assess the costs and benefits of mitigation and use the LEAP tool; (ii) design effective NAMAs and investment proposals and understand the options for accessing international climate finance; and (iii) measure the GHG and other impacts of mitigation actions once they have been implemented.

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[10] 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

[11] Abt Associates. 2014. *Workshop Summary: National Inception Workshop for Azerbaijan*. Baku, Azerbaijan. January 2014. RETA 8119: Economics of Climate Change in Central and West Asia—Mitigation Component. Washington, D.C.; Abt Associates. 2014.

[12] Abt Associates, 2014c. *RETA–8119 REG: Economics of Climate Change in Central and West Asia—Mitigation Component. Interim Report*. Bethesda, 2014.

3. The Study Team

37. The TA was carried out by an internationally recruited US consulting firm, Abt Associates, in association with the Stockholm Environment Institute (SEI), the Swedish non-governmental organization that developed the LEAP software, and Nazar Business and Technology (NBT) in Uzbekistan. The international team included a climate change mitigation specialist, an energy and transport specialist, an economist, and a mitigation investment specialist. Each national team included a climate change mitigation specialist, an energy and transport specialist, and a mitigation investment specialist. The work was carried out under Project Number 44068-012 dated 13 May 2013.

4. Counterparts

38. The implementation of the TA was guided by the Central and West Asia Department in ADB and by the counterparts and other stakeholders in Azerbaijan, Kazakhstan, and Uzbekistan. The national counterparts for the TA are described in Table 4. Throughout the TA, these counterparts have been instrumental in guiding the analytical direction of the work, coordinating stakeholder input, and providing support for data collection and research.

Table 4: National Counterparts in Azerbaijan, Kazakhstan, and Uzbekistan

Country	Agency	Involvement in National Climate Change Planning
Azerbaijan	State Agency for Alternative and Renewable Energy Sources (SAARES)	SAARES is responsible for renewable energy and energy efficiency planning and regulation in Azerbaijan, including tariff policy and elaboration and enforcement of relevant procedures. This includes issuing permits to public and private entities to construct power generation facilities. SAARES is also the lead agency for implementing Azerbaijan's 20% renewable energy target by 2020, the cornerstone of the government's move towards a low-carbon economy. The Department of Investments and Project Management within SAARES serves as the immediate contact point for the TA.
Kazakhstan	Ministry of Energy	The Ministry of Energy is the UNFCCC focal point for climate change and represents Kazakhstan in the international climate change negotiations. The ministry is also responsible for coordinating climate change policy in Kazakhstan and implementing the new GHG emissions trading system. The Department for Climate Change serves as the immediate contact point for the TA. The Ministry of Energy's research organization, JSC Zhasyl Damu, provided technical experts and technical guidance for the development of the economic model.
Uzbekistan	Ministry of Economy Centre of Hydrometeorological Service at Cabinet of Ministers of the Republic of Uzbekistan (Uzhydromet)	The Ministry of Economy is the lead counterpart for the TA in Uzbekistan. The Ministry of Energy sets direction on economic policy related to energy and transport. The Department of Agriculture and Water Management is the immediate contact point for the TA. Uzhydromet is the UNFCCC Focal Point for Climate Change and responsible for preparing Uzbekistan's national GHG emission inventories and national communications. Uzhydromet provides technical direction for the implementation of the TA.

Source: Abt Associates, 2014c. *RETA–8119 REG: Economics of Climate Change in Central and West Asia—Mitigation Component. Interim Report*. Bethesda, 2014.

5. Organization of this Final Report

39. The Final Report comprises five sections. Section III provides a summary of the deliverables produced under Outputs 1 and Outputs 2, including the regional report on the economics of reducing GHG emissions in Azerbaijan, Kazakhstan, and Uzbekistan and the regional report on NAMAs. It also summarizes the investment concept notes developed in support of the NAMAs. The proposed investment concept notes are provided in full in Appendix 2. Section IV discusses results and outputs according to the Design Monitoring Framework for the TA. Section V presents lessons learned and recommendations for next steps.

III. SUMMARY OF DELIVERABLES AND FINDINGS

40. Section III provides a summary of the deliverables and findings from RETA 8119 (the TA). It also describes the results of the TA according to the Design and Monitoring Framework for the TA. The summary starts with a regional overview of the energy and transport sectors of Azerbaijan, Kazakhstan and Uzbekistan (Section A. Existing Regional Overview Context), which serves as a background for the results provided later in Sections B (Costs and Benefits of Mitigation), C (Capacity Development), D (Design of NAMAs), and E (Formulation of Investment Concept Notes).

A. Existing Regional Context in Azerbaijan, Kazakhstan, and Uzbekistan

41. This study focuses on three countries in Central and West Asia: Azerbaijan, Kazakhstan, and Uzbekistan. The region has highly diverse and rich ecological zones, with mountains, flatlands, and deserts in each country. All three countries have growing populations and abundant natural resources, which have helped them liberalize their economies and stimulate development since gaining independence from the Soviet Union in the early 1990s. The expanding populations in all three countries and urbanization in Azerbaijan and Uzbekistan will continue to put pressure on natural resources and the environment.

42. The region has posted strong economic growth over the last decade. Between 2000 and 2010, real Gross Domestic Product (GDP) grew 95% in Uzbekistan, 220% in Kazakhstan, and 400% in Azerbaijan. Per capita real GDP in purchasing power parity (PPP, at constant 2011 international $) improved as well, particularly in Kazakhstan and Azerbaijan. Industry and services together account for over 80% of GDP in the study 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. Table 5 presents the performance of each country according to selected indicators.

Table 5: Selected Social and Economic Indicators of Azerbaijan, Kazakhstan, and Uzbekistan

Indicators	Azerbaijan			Kazakhstan			Uzbekistan		
	2000	2005	2013	2000	2005	2013	2000	2005	2013
Population (million) [a]	8.07	8.50	9.42	14.9	15.1	17.0	24.7	26.2	30.2
Population growth rate (%) [a]	1.1	1.2	1.3	-0.3	0.9	1.4	1.4	1.2	1.6
% Urban population [a]	51.1	52.5	53.2	56.3	57.1	54.9	37.2	36.1	51.2 [a]
GDP per capita, PPP (constant 2011 $) [b]	4,459	8,052	16,593	9,706	15,619	22,470	2,481	3,041	5,002
Growth rate of real GDP [a]	11.1	26.4	5.8	9.8	9.7	6.0	3.8	7.0	8.0
Sector Contribution to GDP (%) [a]									
Agriculture	17	10	6	9	7	5	34	30	19
Industry	45	63	62	40	39	38	23	29	33
Services	38	27	32	51	54	57	43	41	48

GDP = gross domestic product, PPP = purchasing power parity.
Sources:
[a] ADB. 2011. *Key Indicators for Asia and the Pacific 2014, 45th Edition.* Manila.
[b] World Bank. 2015. *World Development Indicators.* http://data.worldbank.org/data-catalog/world-development-indicators

1. Energy Production and Use

43. 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.[13] Table **6** presents the overall structure of the total primary energy supply (TPES) in the region in 2000, 2005, and 2010, which covers energy supply for both energy and transport. Overall total 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. As shown in Table 6, 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. During the period from 2000 to 2010, Uzbekistan showed a growing dependence on natural gas, and the two other countries on petroleum products. Meanwhile, the share of hydropower decreased in Azerbaijan and Kazakhstan and increased in Uzbekistan.

Table 6: Structure of Total Primary Energy Supply in Azerbaijan, Kazakhstan, and Uzbekistan, 2000–2010

Indicators	Azerbaijan			Kazakhstan			Uzbekistan		
	2000	2005	2010	2000	2005	2010	2000	2005	2010
TPES (thousand toe)	12,059	12,858	11,684	53,406	60,701	77,846	49,416	45,597	42,307
Energy resource share in TPES (%)									
Coal				45.9	50.5	44.5	1.7	1.6	2.0
Natural gas	68.3	65.9	67.7	13.7	9.1	10.9	84.4	87.0	86.6
Petroleum products	29.6	31.9	31.1	39.1	39.2	43.6	12.9	10.0	9.4
Hydropower	1.4	1.9	0.6	1.2	1.1	0.9	1.0	1.2	2.0
Wind									
Solar									
Biomass	0.7	0.6	0.8	0.1	0.1	0.1			

Source: ADB. Forthcoming. *Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs.* Manila: ADB.

44. The energy intensity of GDP is defined as energy use (i.e., TPES) per unit of GDP, which provides a picture of an economy's energy use efficiency, i.e., the amount of energy required per dollar of GDP. To compare across countries, GDP in constant 2010 $ was used in this study. All three countries' energy intensity declined from 2000 to 2010, with Uzbekistan showing the most dramatic decline of 55.8% during that time period (Table 7). 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 flat in Uzbekistan.

Table 7: Energy Indicators for Azerbaijan, Kazakhstan, and Uzbekistan, 2000–2010

Indicators	Azerbaijan			Kazakhstan			Uzbekistan		
	2000	2005	2010	2000	2005	2010	2000	2005	2010
TPES per capita (toe)	1.5	1.5	1.3	3.6	4.0	4.8	2.0	1.7	1.5
TPES/GDP (MJ per thousand 2010 $)	38	22	9	29	19	19	154	108	68
Greenhouse gas intensity of TPES (Kg CO_2e/GJ)	66	73	84	89	93	78	56	56	55

Source: ADB. Forthcoming. *Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs.* Manila.

[13] Abt Associates, 2014b. *RDTA–8119 REG: Economics of Climate Change in Central and West Asia—Mitigation Consultant. Inception Report*. Bethesda, 2014.

2. Structure of Electricity Generation

45. Table 8**:** presents the structure of installed electricity generation in Azerbaijan, Kazakhstan, and Uzbekistan. As of 2010, the total installed electricity generation capacity in the region was estimated at 38,468 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. During the period from 2000 to 2010, there was a minor shift to renewables for power generation in Uzbekistan and a slight decrease in Azerbaijan and Kazakhstan.

Table 8: Structure of Installed Electricity Generation Capacity in Azerbaijan, Kazakhstan, and Uzbekistan, 2000 - 2010 (MW)

Capacity (MW)	Azerbaijan			Kazakhstan			Uzbekistan		
	2000	2005	2010	2000	2005	2010	2000	2005	2010
Coal				12,220	12,442	12,605	2,283	2,283	2,283
Natural gas	3,157	3,632	4,780	2,291	2,465	2,936	7,230	8,052	7,835
Petroleum products	970	968	1,037	1,931	1,946	1,949	271	271	271
Hydropower	820	970	785	2,227	2,247	2,255	1,690	1,710	1,730
Wind			1.7						
Solar									0.8
Total	**4,947**	**5,570**	**6,604**	**18,669**	**19,100**	**19,744**	**11,474**	**12,317**	**12,120**

Source: ADB. Forthcoming. *Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs.* Manila: ADB.

3. Greenhouse Gas Emissions

46. As a result of this heavy fossil fuel–based energy mix, the economies of Azerbaijan, Kazakhstan and Uzbekistan are carbon-intensive. As presented in Table 9, total GHG emissions have grown in Azerbaijan and Kazakhstan, while they declined in Uzbekistan, where energy efficiency has improved significantly. In all three countries, more than 75% of total 2010 GHG emissions are a result of activities in the energy and transport sectors.

Table 9: Greenhouse Gas Emissions in Azerbaijan, Kazakhstan, and Uzbekistan, 2000–2010 (million metric tons CO_2e)

	Greenhouse Gas Emissions (Million metric tons CO_2e)		
Country	2000	2005	2010
Azerbaijan	36	44	47
Kazakhstan	208	243	273
Uzbekistan	140	137	127

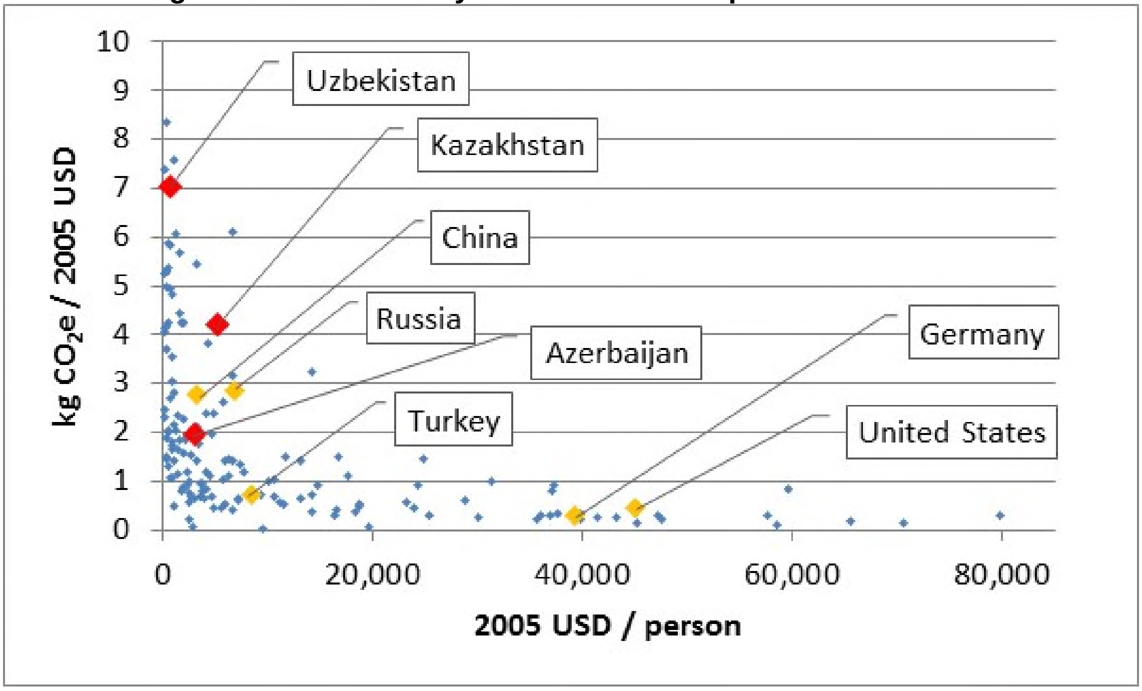
Source: ADB. Forthcoming. *Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs.* Manila: ADB.

47. 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 (Figure 2). Uzbekistan's and Kazakhstan's intensities are notably higher than Azerbaijan's (and China's and Russia's, for example), while Azerbaijan's is somewhat lower but still greater than in nearby countries such as Turkey and Georgia.

48. They continue to rely 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. 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, Azerbaijan, Kazakhstan, and Uzbekistan

are still dealing with the legacy of an energy-intensive Soviet infrastructure, in spite of significant improvements in energy efficiency over the last 15 years, and their power sectors remain dominated by fossil fuel technologies.

Figure 2: GHG Intensity of GDP vs. Per Capita Income in 2012



Sources: World Bank. 2015. *World Development Indicators*. databank.worldbank.org; and European Commission JRC Joint Research Centre. 2015. *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.

4. Energy Resource Potentials

49. The endowment of energy resources favors fossil fuels in all three countries (Table 10). Kazakhstan has abundant coal resources, Azerbaijan has significant oil and natural gas resources, and Uzbekistan has large natural gas resources and modest coal 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.

50. Significant potential for renewables exists, although these are less well understood and will need to be assessed in more detail (Table 11). Uzbekistan has strong potential for solar energy, Kazakhstan has significant wind potential and moderate potential for hydropower, and Azerbaijan has moderate potential for wind and solar energy. Thus, all three countries have significant room to increase the share of renewables in the primary energy mix.

Table 10: Fossil Fuel Reserves

Country	Reserves as of 2011		
	Crude Oil (billion barrels)	Natural Gas (trillion m^3)	Coal (billion tonnes)
Azerbaijan	7	0.9	NA
Kazakhstan	28.6	1.3	35
Uzbekistan	0.6	1.1	1.9

Sources: BP (2014); Ministry of Industry and New Technologies of Kazakhstan (2014); U.S. Energy Information Administration (2014).

Table 11: Renewable Resource Yields

<table>
<tr><th rowspan="2">Country</th><th colspan="5">Annual Yield (billion kWh)</th></tr>
<tr><th>Large hydro</th><th>Small Hydro</th><th>Solar</th><th>Wind</th><th>Biomass</th></tr>
<tr><td>Azerbaijan</td><td>11</td><td>5</td><td>39.6</td><td>86.4</td><td>0.77</td></tr>
<tr><td>Kazakhstan</td><td>51</td><td>11</td><td>4</td><td>930</td><td>NA</td></tr>
<tr><td>Uzbekistan</td><td colspan="2">20.9</td><td>2,055</td><td>4.6</td><td>3.5</td></tr>
</table>

Sources: ADB (2014); Centre of Hydrometeorological Service (2008); Ministry of Ecology and Natural Resources of Azerbaijan Republic (2012); Ministry of Environment and Water Protection of the Republic of Kazakhstan (2013); Mitsubishi Heavy Industries et al. (2014); Suleymenov (2014b); UNFCCC CDM Executive Board (2012b).

B. Costs and Benefits of Climate Change Mitigation: Summary of Results (Output 1)

51. Given the heavy reliance on fossil fuels in Azerbaijan, Kazakhstan and Uzbekistan, there are many ways to reduce or avoid GHG emissions from the energy and transport sectors. Output 1 of the TA assessed the direct costs and benefits and indirect co-benefits of climate change mitigation in these two sectors. Section B summarizes the results, starting with a discussion of the scope and methods used in the assessment. Then the results of the emission projections to 2050 are presented, as well as the cost-benefit assessment of individual mitigation options. Additional documentation is provided in the TA report *Economics of Reducing Greenhouse Gas (GHG) Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan, and Uzbekistan*.[14]

1. Model Scope and Boundaries

52. The modeling of the three countries' energy and transport systems, GHG and air pollutant emissions, GHG mitigation potentials, and direct costs and benefits of mitigation was carried out in two stages. The first stage, related to projecting emissions to 2050 and analyzing the direct costs and benefits of mitigation, was done in LEAP. The second stage, related to analyzing the co-benefits of mitigation, was prepared as follows:

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

53. The scope of the analysis is summarized in Table 12.

Table 12: Scope and Analytical Approach

<table>
<tr><th rowspan="3">Subsector</th><th rowspan="3">Direct Costs and Benefits Modeled in LEAP</th><th colspan="6">Co-benefits</th></tr>
<tr><th rowspan="2">Air Pollution Reduc-tion</th><th rowspan="2">Human Health (i.e., reduced mortality)</th><th colspan="4">Energy Security</th></tr>
<tr><th>Fuel Saving</th><th>Energy intensity</th><th>Carbon intensity</th><th>Percent share of renewables in energy supply</th></tr>
<tr><td>Electricity generation</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td>Heat Generation</td><td>✓</td><td>✓</td><td></td><td>✓</td><td>✓</td><td>✓</td><td>✓</td></tr>
<tr><td>Transport</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td><td>✓</td><td></td></tr>
</table>

Source: ADB. Forthcoming. *Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs.* Manila: ADB.

[14] ADB. Forthcoming. *Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs.* Manila: ADB.

a. Modeling of Direct Costs and Benefits

54. The consultants used LEAP to project emissions to 2050 with no mitigation action and to analyze the costs and benefits of individual mitigation scenarios. This was done by developing a national LEAP model for each of Azerbaijan, Kazakhstan, and Uzbekistan. These national models estimate all GHG emissions from energy, transport, and non-energy sources as well as emissions of other significant air pollutants from energy use. Table 13 lists the GHGs and air pollutants covered.

55. LEAP can report estimates of GHG emissions in terms of the mass of each individual pollutant (e.g., tonnes of methane) or as CO_2e. Conversions to CO_2e can be carried out using 20, 100, or 500-year global warming potentials (GWPs). For this TA, all quantities of CO_2e are calculated using the 100-year GWPs in the Intergovernmental Panel on Climate Change's (IPCC) *Second Assessment Report.*[15]

Table 13: GHGs and Air Pollutants Covered in the National Cost-Benefit Models

Greenhouse Gases	Air Pollutants
- Carbon dioxide - Methane - Nitrous oxide - Hydrofluorocarbons, perfluorocarbons, sulfur hexafluoride, and other high global warming potential (GWP) gases	- Carbon monoxide - Nitrogen oxides - Non-methane volatile organic compounds - Particulate matter - Sulfur dioxide

Source: ADB. Forthcoming. *Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs.* Manila: ADB.

56. The models incorporate an accounting of direct costs and benefits of the energy and transport systems and mitigation measures. These costs and benefits are *social* costs and benefits, meaning that they are figured 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) Operating and maintenance costs;
(iii) Fuel costs; and
(iv) Other implementation costs for mitigation measures (e.g., governmental program administration costs).

57. Reductions in any of these costs as a result of mitigation are considered a benefit. For instance, decreased fuel costs due to an efficiency measure would be a benefit. All direct costs and benefits are expressed in real (constant monetary year) terms in the models.[16] When discounted costs are reported, a 7% real discount rate is used.

58. The national models comprise both historical data and projections of energy use, emissions, and costs. The historical period in each model was determined by available data, notably national energy balances and fuel price data which the consultants obtained with the help of national stakeholders in each country. The Interim Report for the TA provides a detailed description of the type of data collected and the process used for data collection.[17] All data and assumptions used for developing the models are documented in the final versions of the national models, which will be published on ADB's website along with the TA

[15] Houghton, John Theodore, and Intergovernmental Panel on Climate Change, eds. 1996. *Climate Change 1995: The Science of Climate Change*. Cambridge ; New York: Cambridge University Press.
[16] Economic variables including GDP, value added, and fuel prices are also expressed in real terms in the models.
[17] Abt Associates, 2014c. *RETA–8119 REG: Economics of Climate Change in Central and West Asia—Mitigation Component. Interim Report*. Bethesda, 2014.

report *Economics of Reducing Greenhouse Gas (GHG) Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan, and Uzbekistan*.[18]

59. The projections in all three models run through 2050. Table 14 defines the historical and projection periods in the three LEAP models.

Table 14: Model Years

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

Source: ADB. Forthcoming. *Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs.* Manila: ADB.

b. Indirect Co-Benefits

60. The analysis of the indirect co-benefits 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.

61. The human health assessment focuses on the benefits of reduced air pollutant concentrations from mitigation options that reduce emissions from electricity generation and transport. It does not cover emissions from mitigation options that reduce emissions from heating. Electricity and transport are the two subsectors for which sufficient data and methods are available for establishing a quantifiable relationship between air pollutants and health co-benefits, such as reduced mortality.

62. The human health benefits analysis is 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 (U.S. EPA, 2011). As documented in the *Interim Report* for this TA, inhaling $PM_{2.5}$ can lead to adverse health outcomes in humans, including premature mortality.[19] This TA estimates the avoided mortalities from reducing primary $PM_{2.5}$, and the associated SO_2, and NO_x, and then monetizes the value of these avoided mortalities.

63. The consultants 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. Several metrics are applied in this report to analyze whether Azerbaijan, Kazakhstan, or Uzbekistan are becoming more or less energy secure. These metrics include the following:

(i) Fuel savings (million gigajoules);
(ii) Energy intensity (energy consumption per unit of GDP);
(iii) Carbon intensity (CO_2 emissions per unit of GDP); and
(iv) Percentage share of renewable energy in energy supply.

2. Emission Scenarios

64. Evaluation of emission scenarios is a central feature of the economic analysis conducted for this study. A scenario is an internally consistent, physically plausible storyline that

[18] ADB. Forthcoming. *Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs.* Manila: ADB.
[19] Abt Associates, 2014c. *RETA–8119 REG: Economics of Climate Change in Central and West Asia—Mitigation Component. Interim Report*. Bethesda, 2014.

describes how the economy, energy and transport system, pollutant emissions, and costs might evolve over time. It includes exogenous inputs or assumptions and modeling outputs calculated on the basis of the assumptions.

65. The analysis for this TA includes the following four types of scenarios:

(4) A *no action* scenario which assumes that historical trends will continue in the future and that no new mitigation measures will be implemented. The *no action* scenario projects emissions to 2050;
(5) Technical mitigation mini-scenarios which analyze one discrete physical or behavioral mitigation option or technology in comparison with the *no action* scenario, such as a change in technology deployment, differential resource management practices, or the attainment of a non-price target;
(6) Mitigation pricing mini scenarios which add one discrete price-based mitigation option to the *no action* scenario, such as a change in fuel or carbon prices; and
(7) Combined mitigation scenarios. These assume a portfolio of one or more of the technical mitigation mini-scenarios listed in the second bullet.

66. This TA analyzes the marginal impact of both individual mitigation options (technical mitigation mini-scenarios and pricing mini-scenarios) as well as a bundle of mitigation options implemented simultaneously (combined mitigation scenarios). This approach facilitates the analysis of particular mitigation options and the potential interactions of mitigation technologies and practices.

a. The No Action Scenario

67. The foundational scenario in this study is the *no action* scenario. 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. In other words, it assumes the past is an essentially reliable guide to the future. 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. Table 15 lists key targets and policies in each country that are excluded from the *no action* scenario and instead are analyzed as mitigation options.

Table 15: 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. Forthcoming. *Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs.* Manila: ADB.

68. The *no action* scenario comprises both historical data and a projection to 2050 and serves as the reference case against which all mitigation options and scenarios are analyzed. All mitigation scenarios inherit from the *no action* scenario and are measured in comparison to it. The following methods are applied in the development of this scenario:

(i) In each model's historical period (defined in Table 14), energy use and emissions of GHGs and other air pollutants are derived from historical data obtained from each country. Energy supply and demand are determined from historical energy balances, and energy- and transport-related emissions are calculated by multiplying quantities of fuels by emission factors. Non-energy GHG emissions are taken from national GHG emission inventories.

(ii) In the projection period to 2050 (defined in Table 14), emissions from energy and non-energy sources are estimated differently, with much more detail afforded to the energy and transport sectors since this study focuses on these sectors. Emissions from non-energy sources are addressed to provide a picture of total GHG emissions in each country.

(iii) Projections for the energy and transport systems begin with projections of energy supply and demand. Final demand (by fuel) is determined first, after which supply is matched to demand. Energy-related emissions are then calculated in the same way as in the historical period: by multiplying quantities of fuels by emission factors.

(iv) Direct costs and benefits (i.e., social costs) are projected by defining unit costs for equipment, activities, and fuels and multiplying them by equipment requirements, activity levels, and fuel consumption calculated in the energy and transport system model.

(v) Real unit costs are allowed to change in the projection period for the *no action* scenario if there is justification in the literature for doing so. This is the case for some power and vehicle technology costs, as well as for fuels.

(vi) Each national model uses an exogenously specified fuel price. Historical fuel price data are derived from national sources, and future prices are projected by extrapolating historical trends. Due to the highly regulated price regimes in Azerbaijan, Kazakhstan, and Uzbekistan this approach was used rather than indexing to international price forecasts. As a result, projected prices for individual fuels differ across countries. Accounting for subsidies would raise the social cost of fuels in all three study countries, particularly for oil and gas products. Such a change would improve the cost-effectiveness (i.e., lower the cost per tonne of CO_2e abated) of mitigation options that save fossil energy—the majority of options in this study However, as stakeholders in the project's interim workshops expressed skepticism about international estimates of subsidies, these data are not incorporated in this analysis.[20] The net result is a more conservative cost assessment of mitigation than would otherwise be the case.

69. Three significant cross-cutting variables are used in the models: population, GDP, and value added. All three are exogenous inputs. Projections for these are developed using the methods described in Table 16. Figure 3, Figure 4, and Table 17 illustrate the projection results for population and GDP in the *no action* scenario. As demonstrated in the figures, population and real personal income are projected to rise. The growth is steepest in Uzbekistan and Kazakhstan but substantial in all countries.

Table 16: Projection Techniques for Population, GDP, and Value Added

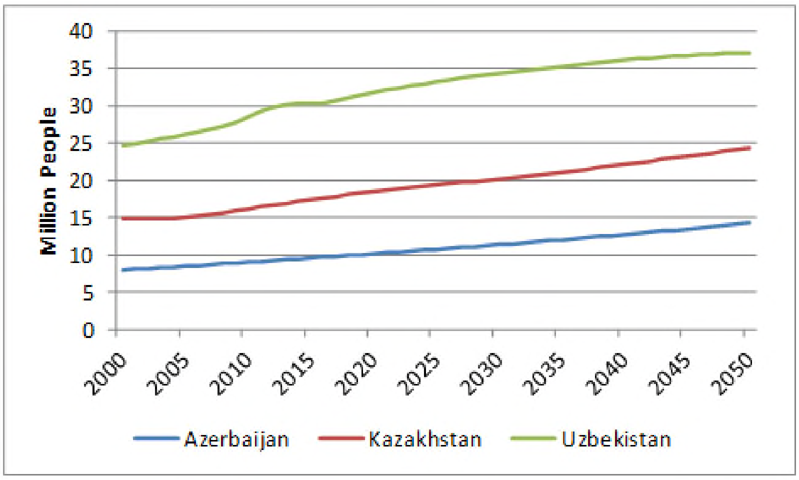
Country	Variable	Projection Technique
Azerbaijan	Population	Growth at average annual 1.14% rate observed in historical data during 2000 to 2010.
	GDP	Short-term projections of 4.3% per year (2013 through 2019) from International Monetary Fund (2014); after 2019, growth at average annual 3.6% rate observed 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

[20] Except for the Fossil Subsidy Removal scenario in the Azerbaijan model.

Country	Variable	Projection Technique
		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 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 UNDP 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).

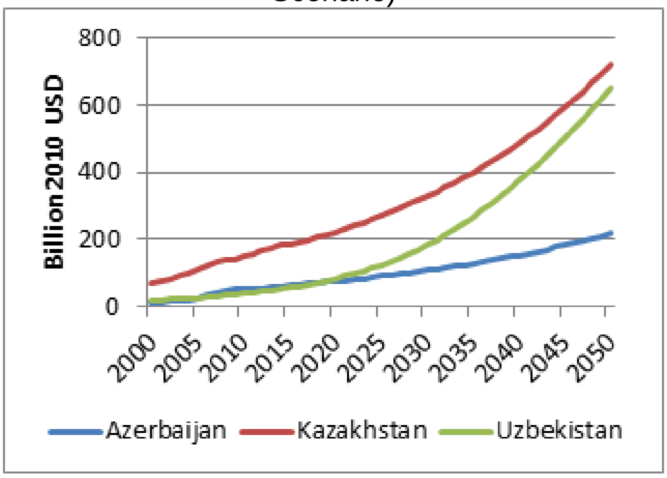
[a] Changes are limited to a few percent per year to avoid unreasonable developments over the long term.
Source: ADB. Forthcoming. *Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs.* Manila: ADB.

Figure 3: Population in Azerbaijan, Kazakhstan, and Uzbekistan (No Action Scenario)



Source: ADB. Forthcoming. *Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs.* Manila: ADB.

Figure 4: GDP in Azerbaijan, Kazakhstan, and Uzbekistan (No Action Scenario)



Source: ADB. Forthcoming. *Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs.* Manila: ADB.

Table 17: Population and GDP in Azerbaijan, Kazakhstan, and Uzbekistan (No Action Scenario)

Country	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
	GDP (Billion 2010 $)										
Azerbaijan	13.2	24.8	52.9	62.9	75.4	90.0	107.4	128.2	153.0	182.6	218.0
Kazakhstan	66.9	109.5	148.1	186.5	221.9	270.0	328.5	399.7	486.2	591.6	719.8
Uzbekistan	19.5	25.3	38.0	56.4	83.59	124.0	183.8	266.6	372.5	501.4	649.7
	Population (Million People)										
Azerbaijan	8.0	8.4	9.0	9.6	10.1	10.7	11.3	12.0	12.7	13.5	14.2
Kazakhstan	14.9	15.1	16.2	17.4	18.5	19.4	20.2	21.1	22.1	23.2	24.3
Uzbekistan	24.7	26.2	28.6	31.0	32.6	33.0	34.1	35.0	35.7	36.1	36.3

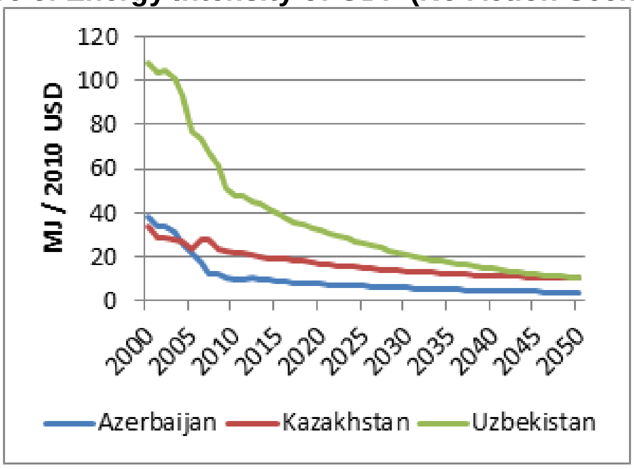
Source: ADB. Forthcoming. *Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs.* Manila: ADB.

70. The assumptions and methods used for the development of the *no action* scenario are described in full detail in the TA report *Economics of Reducing Greenhouse Gas (GHG) Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan, and Uzbekistan.*[21] The methods used were confirmed with stakeholders during the project's interim and final workshops.

71. The *no action* scenario assumes a continuation of the current trend towards energy efficiency improvements in the energy and transport systems in all three countries, which has resulted in a continued decline in the energy intensity of GDP. Figure 5 and Table 18 show the energy intensity of GDP emerging from the *no action* scenario.

72. As evidenced in the figure and table, all three countries have experienced significant improvement in this indicator over the last decade, and the *no action* projection anticipates continued progress on this trend at a slightly slower trajectory. Several factors contribute to the intensity changes that are assumed to occur in the three countries. These include the realization of energy efficiency improvements in the power sector such as rehabilitation of existing plants, gradual retirement of existing plants and replacement with more efficient contemporary technology, and some deployment of renewables. In the transport sector, old, inefficient vehicles are eventually taken off the road and replaced by newer, more efficient models. Finally, for the demand-side sectors, the econometric projections of energy demand lead to lower energy intensity in some cases.

Figure 5: Energy Intensity of GDP (No Action Scenario)



Source: ADB. Forthcoming. *Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs.* Manila: ADB.

[21] ADB. Forthcoming. *Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs.* Manila: ADB.

Table 18: Energy Intensity of GDP (No Action Scenario, MJ / 2010 $)

Country	2000	2010	2020	2030	2040	2050
Azerbaijan	38.4	9.2	7.5	5.8	4.5	3.7
Kazakhstan	33.6	22.1	16.7	13.4	11.4	10.3
Uzbekistan	108.0	47.6	32.0	21.1	14.4	10.3

Source: ADB. Forthcoming. *Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs.* Manila: ADB.

b. Technical Mitigation Mini-Scenarios

73. Technical mitigation mini-scenarios add one discrete mitigation option to the *no action* scenario. The technical mini-scenarios for each country were developed through consultations with national governments and key stakeholders. Each scenario was based on mitigation options that have been considered in the particular country and for which there is national input data on the impacts and costs of the corresponding mitigation option. These requirements ensure that the mitigation options are appropriate and feasible in each country. For the purposes of this study, nationally appropriate data are data produced in the modeled country or, in a few cases, data produced in a neighboring country or region that are clearly applicable to the country.[22]

74. The consultant team defined the technical mini-scenarios and obtained the necessary input data (i.e., mitigation cost and potential) through reviews of national literature and consultations with national stakeholders. The design of the mitigation scenarios was also discussed with stakeholders during the TA's national interim workshops and LEAP trainings to ensure that they accurately represent national development priorities.

75. In cases where no national modeling inputs could be identified for a potential mitigation option referenced in the literature or in national development plans, the consultants did not create any mitigation options. As a result, a certain amount of feasible mitigation potential is missing from each national model. For example, in the case of Azerbaijan and Uzbekistan, there is insufficient data to analyze the cost of reducing fugitive methane emissions from oil and gas production even though the potential for emissions abatement is significant.

76. Table 19 lists the technical mini-scenarios considered for Azerbaijan, Kazakhstan, and Uzbekistan.

Table 19: Technical Mitigation Mini-Scenarios for Azerbaijan, Kazakhstan, and Uzbekistan

Name	Sector	Description
Azerbaijan		
Residential CFL Lighting	Residential	By 2030, all lightbulbs in both urban and rural households are high-efficiency compact fluorescent (CFL) bulbs, using 75% less energy than incandescent bulbs. Based on Ministry of Ecology and Natural Resources of Azerbaijan Republic (2012).
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).
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).
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).
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

[22] Pricing mini-scenarios that explore the effects of harmonization with international prices are an exception. Target prices in this case are necessarily based on international data.

Name	Sector	Description
		households have such stoves by 2030. Based on The Republic of Azerbaijan (2013).
Samukh Agro-Energy Complex	Agriculture/ Residential	Construction of the Samukh Agro-Energy Complex according to Findsen (2015a), 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.
Commercial CFL Lighting	Commercial/ Services	By 2030, all lightbulbs in commercial establishments are high-efficiency compact fluorescent bulbs. Based on Ministry of Ecology and Natural Resources of Azerbaijan Republic (2012).
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.
Rail Electrification	Transport	Alternating current (AC) electrification of railways that are not electrified in the *no action* scenario. Full implementation is expected by 2050. Based on World Bank (2013) and other sources.
AC Rail Conversion	Transport	Conversion to 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 (2013) and other sources.
SOCAR Eco-driving	Transport	Implementation of an eco-driving program for SOCAR's vehicle fleet, beginning in 2015. Based on UNDP (2014).
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).
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).
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).
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).
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).
SAARES Short-term Plans	Electricity Production	New capacity targets for large and small hydro, onshore wind and utility-scale photovoltaic plants 2015–2018. Targets are provided by the State Agency for Alternative and Renewable Energy Sources of the Republic of Azerbaijan (2014).
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).
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).
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).
Kazakhstan		
Advanced Windows	Residential	Replacement of inefficient windows in urban households using windows with a higher insulation value, beginning with 1200 urban apartment buildings by 2020, and reaching all currently existing urban households by 2040. Costs and energy savings from Ergonomika (2011).
Improved Insulation	Residential	Improvement of insulation in urban residential walls and ceilings, beginning with 1200 urban apartment buildings by 2020, and reaching all currently existing urban households by 2040. Costs and energy savings from Ergonomika (2011).
Improved Heat Pipe Insulation	Residential	Improvement of internal 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).

Name	Sector	Description
Internal Heating Network Improvements	Residential	Improvement of internal heating distribution network in urban households, beginning with 1200 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).
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 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).
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.
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).
CNG Passenger Cars	Transport	Integration of an additional 3000 Euro M1 category compressed natural gas passenger vehicles by 2015, rising to 50,000 vehicles beyond the no action scenario by 2018. Based on information from NGV Global (2010).
CNG Fleet	Transport	Sales of 325,000 cars, 45,000 buses and 60,000 trucks by 2025, to meet CNG conversion targets laid out by the RETA 8119 NAMA concept to foster use of natural gas in the transport sector, displacing sales of gasoline and diesel vehicles which would otherwise occur.
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.
Euro-5 Vehicles	Transport	Beginning in 2016, only vehicles adhering to Euro 5 standards may be sold. Based on Dzhaylaubekov (2014).
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.
Expanded Nuclear Power	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).
Optimistic Nuclear Power	Electricity Production	In addition to nuclear capacity that is introduced in the *no action* scenario (900 MW by 2030), and additional 1800 MW of capacity is brought online in 2023 in Kurchatov, based on input from national partners.
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).
Alternative Power Target [a]	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).
Natural Gas Power Target [b] (Green Growth target)	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).
CO_2 Cap on Power Generation [c] (Green Growth target)	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).
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).
Uzbekistan		
Residential	Residential	Reductions in residential building specific energy consumption (total energy

Name	Sector	Description
Building Efficiency		demand/m² floor space) due to enhanced efficiency standards for new buildings and retrofits of existing buildings. The 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).
Residential Renewable Energy	Residential	Deployment of solar photovoltaic, 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).
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).
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).
Electricity Grid Improvements	Electricity Production	Reductions in electricity transmission and distribution losses due to grid improvements. The total losses reach 15% by 2030 and 10% by 2050. Based on UNDP (2015).
Small Hydro	Electricity Production	Small hydropower component of the State Program on Development of Hydropower: 688.5 MW capacity expansion of small hydro by 2030 (Khalmirzaeva, 2015a). New capacity is in addition to that constructed in the *no action* scenario.
Large Hydro	Electricity Production	Large hydropower component of the State Program on Development of Hydropower: 1,824 MW capacity expansion of large hydro by 2030 (Khalmirzaeva, 2015a). New capacity is in addition to that constructed in the *no action* scenario.
Solar Photovoltaic	Electricity Production	Construction of sufficient solar photovoltaic capacity by 2030, to meet 15% of existing capacity in 2014. Based on the “Optimistic” development trajectory described in STA et al. (2014b).
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).
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).

[a] In addition to the Alternative Power Target described here, targets of a) 3% by 2020, 20% by 2030 and 40% by 2050, and b) 3% by 2020, 10% by 2030 and 30% by 2050 were implemented.
[b] In addition to the Natural Gas Power Target described here, targets of a) 15% by 2020, 20% by 2030 and 25% by 2050, and b) 20% by 2020, 30% by 2030 and 50% by 2050 were implemented.
[c] In addition to the CO_2 cap described here, targets of (a) -1.5% by 2015, -5% by 202 and -10% by 2030, and (b) -5% by 2015, -10% by 2020, -20% by 2030 and -50% by 2050 were implemented.
Source: ADB. Forthcoming. *Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs.* Manila: ADB.

c. Pricing Mitigation Mini Scenarios

77. Pricing mini-scenarios add one discrete price-based mitigation option to the *no action* scenario, such as a change in fuel or carbon prices. Pricing scenarios are analyzed separately because they can engage one or more of the technical mini-scenarios listed above and therefore address overlapping emission sources. For example, the scenarios based on phasing out fossil fuel subsidies in Azerbaijan and Kazakhstan engage all technical options that are cost-effective under the new prices

78. Table 20 lists the pricing mini-scenarios considered for Azerbaijan and Kazakhstan. No pricing scenarios were developed for Uzbekistan given the limited availability of historical fuel price data to inform the development of a price-responsive model for that country.

Table 20: Pricing Mini-Scenarios for Azerbaijan and Kazakhstan

Name	Sector	Description
Azerbaijan		
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).
OECD Fuel Prices	All sectors	Prices for major fuels equalize with current (2013) OECD averages by 2030. Based on IEA (2014a).
Carbon Tax [a] (EU Harmonization)	All sectors	Implementation of the following gradual carbon tax schedule (all taxes in 2010 USD): $5 by 2015, $15 by 2020, $25 by 2030 and $50 by 2050. Based on Abt Associates et al. (2014a).
Kazakhstan		
OECD Fuel Prices	All sectors	Prices for major fuels equalize with current (2013) OECD averages by 2030. Based on IEA (2014a).
Emissions Trading Scheme (ETS)	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.
Extended Emissions Trading Scheme	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.

[a] In addition to the carbon tax schedule described here, targets of a) $5 by 2015, $12 by 2020, $20 by 2030 and $50 by 2050, and b) $5 by 2015, $8 by 2020 and $16 by 2030 and $35 by 2050 were implemented.
Source: ADB. Forthcoming. *Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs.* Manila: ADB.

d. Combined Mitigation Scenarios

79. Combined mitigation scenarios combine multiple technical mini-scenarios into a portfolio of mitigation options. The combined scenarios focus on combinations of technical options only, because the pricing mini-scenarios by default engage all technical options that are cost-effective under the new prices. Thus, the pricing mini-scenarios already represent self-consistent combinations of technical measures.

80. Table 21 lists the combined mitigation scenarios considered for each country.

Table 21: Combined Mitigation Scenarios for Azerbaijan, Kazakhstan, and Uzbekistan

Name	Sector	Description
Azerbaijan		
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%.
Renewable Power Target	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.
All Low-Cost Technical Measures	All sectors	A combined scenario including all technical mini-scenarios whose cumulative discounted direct cost per tonne of GHG reductions <= 10 2010 USD.
All Moderate-Cost Technical Measures [a]	All Sectors	A scenario quantifying potential moderate-cost technical mitigation options for Azerbaijan. Includes all individual mitigation options whose cumulative discounted direct cost per tonne of GHG reductions <= 50 2007 AZN.
All Technical	All sectors	A combined scenario including all technical mini-scenarios showing

Name	Sector	Description
Measures		abatement potential.
Kazakhstan		
All Low-Cost Technical Measures	All sectors	A combined scenario including all technical mini-scenarios whose cumulative discounted direct cost per tonne of GHG reductions <= 10 2010 USD.
All Technical Mini-Scenarios	All Sectors	All technical mini-scenarios with positive abatement potential are combined into a full mitigation scenario. Overlaps between specific measures are addressed individually, as needed.
Uzbekistan		
All Low-Cost Technical Measures	All sectors	A combined scenario including all technical mini-scenarios whose cumulative discounted direct cost per tonne of GHG reductions <= 10 2010 USD.
All Technical Mini-Scenarios	All Sectors	All technical mini-scenarios with positive abatement potential are combined into a full mitigation scenario. Overlaps between specific measures are addressed individually, as needed.

[a] This scenario responds to a request from Azerbaijan's UNFCCC focal point to analyze a potential emission reduction scenario for consideration for Azerbaijan's Intended Nationally Determined Contribution (INDC).
Source: ADB. Forthcoming. *Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs.* Manila: ADB.

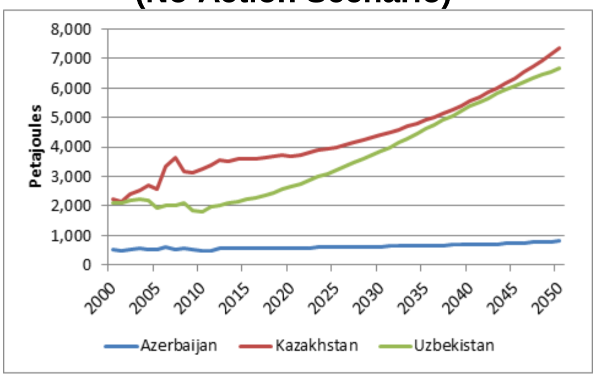
3. Results: GHG Emission Projections to 2050 in the No Action Scenarios

81. The following subsection provides the results of the *no action* emission scenarios for Azerbaijan, Kazakhstan, and Uzbekistan. As discussed in Section III.B.2.a the development of these scenarios is based on several assumptions regarding population, GDP growth, fuel mix, and fuel prices which inform energy supply and demand and resulting GHG emissions through 2050.

82. Figure 6 and Table 22 depict the total primary energy supply projections through 2050 in the *no action* scenario which, in all three countries, are expected to more than double or triple. This means that, in each country, the declining energy intensity demonstrated in Figure 5 and Table 18 is more than outweighed by the increased supply requirements associated with rising population and income. The growth is particularly dramatic in Kazakhstan and Uzbekistan which also expect the highest annual GDP growth during this study period.

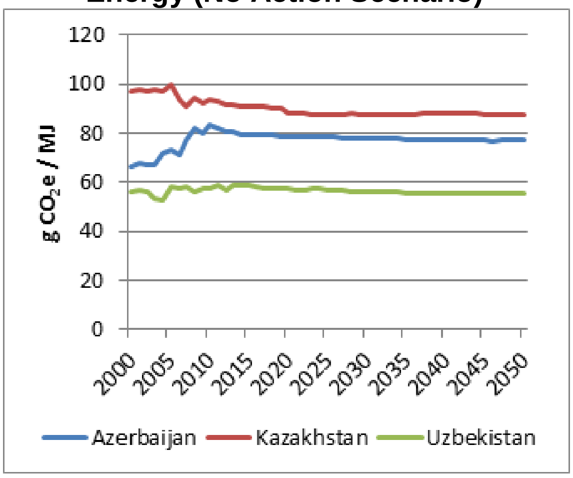
83. As Figure 7 and Table 23 illustrate, the overall GHG intensity of energy supply is not projected to change significantly. Fundamentally, this is due to continued reliance on fossil fuels in buildings and for industry, transport, and power—oil and natural gas in Azerbaijan, oil and coal in Kazakhstan, and natural gas in Uzbekistan.

Figure 6: Total Primary Energy Supply (No Action Scenario)



Source: ADB. Forthcoming. *Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs.* Manila: ADB.

Figure 7: Carbon GHG Intensity of Energy (No Action Scenario)



Source: ADB. Forthcoming. *Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs.* Manila: ADB.

Table 22: Total Primary Energy Supply (No Action Scenario, Petajoules)

Country	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Azerbaijan	505	538	489	553	569	593	623	652	695	733	801
Kazakhstan	2,248	2,553	3,266	3,596	3,700	3,990	4,416	4,905	5,549	6,346	7,382
Uzbekistan	2,103	1,940	1,810	2,227	2,673	3,207	3,871	4,609	5,379	6,079	6,669

Source: ADB. Forthcoming. *Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs.* Manila: ADB.

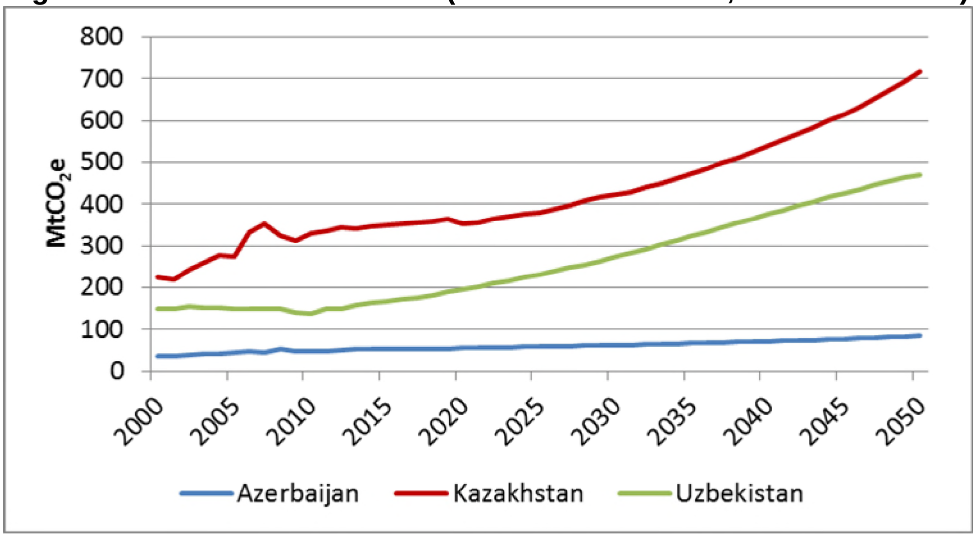
Table 23: Carbon Intensity of Energy (No Action Scenario, gCO_2e / MJ)

Country	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Azerbaijan	66.0	72.9	83.6	79.3	78.8	78.4	77.9	77.5	77.5	76.9	76.9
Kazakhstan	96.7	99.9	93.7	90.9	88.0	87.6	87.7	87.5	88.0	87.7	87.5
Uzbekistan	56.3	58.0	57.7	58.9	57.2	56.8	55.9	55.7	55.7	55.7	55.7

Source: ADB. Forthcoming. *Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs.* Manila: ADB.

84. The increasing demand for carbon-intensive energy, driven by population and income growth, leads to rising GHG emissions in all three countries, particularly in Kazakhstan and Uzbekistan. Combining the energy and transport system results with simple projections of non-energy GHG emissions produces the projections in Figure 8 and Table 24.

Figure 8: Total GHG Emissions (No Action Scenario, 100-Year GWPs)



Note: GWP = Global warming potential
Source: ADB. Forthcoming. *Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs.* Manila: ADB.

Table 24: Total GHG Emissions (No Action Scenario, $MtCO_2e$)

Country	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
Azerbaijan	36.2	44.2	47.1	52.1	54.6	57.9	61.8	65.9	71.3	76.1	83.8
Kazakhstan	223.1	275.3	328.6	349.6	352.0	380.2	422.9	471.4	538.0	615.4	715.7
Uzbekistan	148.0	147.6	137.0	167.6	195.1	230.9	273.2	322.7	375.9	425.7	469.9

Source: ADB. Forthcoming. *Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs.* Manila: ADB.

85. Between 2010 and 2050, total projected GHG 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 a growing potential to reduce fossil fuel emissions through efficiency, fuel switching, and other measures. Within energy and transport, certain source categories are especially salient given their

contributions to the 2050 total and growth during the projection period, as depicted in Table 25.

Table 25: Significant GHG Emission Source Categories in Energy and Transport (No Action Scenario)

Country	Source	Share of 2050 GHG Emissions (%)	2010–2050 Growth (%)
Azerbaijan	Gas Production and T&D	19	35
	Residential	18	128
	Transport	14	133
	Electricity and CHP	11	14
Kazakhstan	Industry	27	86
	Electricity and CHP	20	99
	Heat Production	12	139
	Residential	11	379
	Coal Mining	6	79
Uzbekistan	Industry	22	678
	Electricity and CHP	11	100
	Residential	9	184
	Gas Processing	9	49
	Transport	8	881

Source: ADB. Forthcoming. *Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs.* Manila: ADB.

86. Many of these categories or sectors are the target of mitigation options explored in this study, but some—such as fossil fuel extraction in Uzbekistan (or fossil extraction for export in Azerbaijan)—are not. Focusing future national planning on mitigation opportunities in these sectors could have significant impact on future emission trajectories.

4. Costs and Benefits of Mitigation in Azerbaijan, Kazakhstan, and Uzbekistan

87. The following subsection summarizes the results of the direct cost-benefit analysis of the proposed mitigation scenarios as compared with the *no action* scenario outlined in Section III.B.2. The results are organized according to type of mitigation scenario: technical mitigation mini-scenario, pricing mini-scenario, or combined scenario.

88. The analysis of direct costs and benefits of mitigation considers two primary questions: the mitigation potential (tonne of CO_2e reduced) and the cost-effectiveness (cost per tonne of CO_2e) of each discrete mitigation option.

89. A key issue in the estimation of mitigation potential and costs per tonne is how to account for interactions between mitigation options. Implementing certain options together can lower (or raise) their total effectiveness. This study addresses this issue following the retrospective systems approach in Sathaye and Meyers (1995) by following four steps:

(i) Each mitigation option is first evaluated individually (compared to the *no action* case), and an initial cost per tonne for each is recorded;
(ii) The options are sorted according to their initial costs per tonne in ascending order;
(iii) The options are added one at a time and in order to a new combined mitigation scenario, and emissions and costs for the combined scenario are recorded after each addition; and
(iv) The final abatement potential and cost per tonne for each option are calculated using the marginal emission reductions and costs incurred after the option was added to the combined scenario. Thus, the first option is evaluated in comparison to the *no action* scenario only, the second option in comparison to the *no action* scenario plus the first option, and so forth.

90. Table 26 summarizes the abatement potentials and costs for the technical mitigation mini-scenarios included in the study and Table 27 summarizes these for the pricing and combined scenarios. For comparison between countries, the final column on the right presents reduction costs in a common currency of 2010 $.

Table 26: Costs and Abatement Potentials for Technical Mitigation Mini-Scenarios

Azerbaijan			
Scenario	**Cumulative Potential GHG Emission Reductions [a] [tCO_2e]**	**Reduction Cost per Tonne [2007 AZN / tCO_2e]**	**Reduction Cost per Tonne [2010 $ / tCO_2e]**
Euro 4 Vehicle Standards	12,301,298	-47.7	-70.2
SOCAR Eco-driving	1,926,241	-43.2	-63.6
Commercial CFL Lighting	44,199,773	-6.3	-9.3
Residential CFL Lighting	76,763,797	-5.8	-8.5
Forests 20% of Total Land Area	45,706,558	0.5	0.8
Forests 12.5% of Total Land Area	8,466,758	0.9	1.3
Improved Insulation	72,144,742	1.0	1.5
Small Hydro	33,939,169	1.3	1.9
Sustainable Land Management	12,052,454	2.2	3.3
Onshore Wind	15,534,982	5.8	8.5
Samukh Agro-Energy Complex	4,074,171	6.8	10.0
Renewable Power Target[23]	32,550,700	24.2	35.6
3 MW Small Solar	93,009	28.6	42.0
Municipal Solid Waste to Energy	4,751,891	56.5	83.1
Biogas	1,963,020	124.2	182.7
Electricity Network Upgrade	20,107,941	236.2	347.3
AC Rail Conversion	529,352	325.0	477.8
Solar Hot Water	1,416,631	379.5	558.0
Efficient Stoves	196,768	773.9	1,137.8
Rail Electrification	91,026	909.4	1,337.1
SAARES Short-Term Plans	0	NA[b]	NA[b]
Kazakhstan			
Scenario	**Cumulative Potential GHG Emission Reductions [a] [tCO_2e]**	**Reduction Cost per Tonne [2010 KZT / tCO_2e]**	**Reduction Cost per Tonne [2010 $ / tCO_2e]**
CNG Fleet	27,295,626	-12,170.7	-82.6
CNG Passenger Cars	1,453,274	-2,786.3	-18.9
Improved Heat Pipe Insulation	166,006,789	-292.3	-2.0
Coalbed Methane Capture	94,167,987	-139.5	-0.9
Efficient New Homes	238,762,921	-43.4	-0.3
Natural Gas Power Target (Green Growth)	399,039,208	337.0	2.3
Internal Heating Network Improvements	404,198,552	507.4	3.4
CO_2 Cap on Power (Green Growth)	673,820,538	558.4	3.8

[23] The Renewable Power Target Scenario is 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.

Improved Insulation	395,591,779	1,007.6	6.8
Advanced Windows	77,757,249	1,808.7	12.3
Heat Distribution Upgrades	159,352,071	2,877.4	19.5
Alternative Power Target	217,505,879	4,457.0	30.2
Expanded + Optimistic Nuclear Power[24]	38,826,060	4,771.7	32.4
Rehabilitation of National Grid	21,979,657	13,991.4	95.0
Urban LED Lighting	459,737	19,499.8	132.3
Waste to Energy	-142,956	NA[b]	NA[b]
Euro 5 Vehicles	-10,237,033	NA[b]	NA[b]
Early Vehicle Retirement	-31,179,955	NA[b]	NA[b]
Uzbekistan			
Scenario	**Cumulative Potential GHG Emission Reductions [a] [tCO_2e]**	**Reduction Cost per Tonne [2013 UZS / tCO_2e]**	**Reduction Cost per Tonne [2010 $ / tCO_2e]**
Residential Building Efficiency	569,147,765	-111,064.7	-44.9
Large Hydro	110,835,506	-100,493.5	-40.7
Small Hydro	22,924,927	-51,184.7	-20.7
Residential Renewable Energy	26,166,554	-24,043.9	-9.7
Alternative Vehicles	128,471,751	1,546.2	0.6
Heat Network Improvements	48,112,419	19,898.4	8.1
Heat Plant Efficiency	71,424,254	45,803.2	18.5
Solar Photovoltaic	31,200,307	60,451.5	24.5
Electricity Grid Improvements	57,640,715	223,258.6	90.3
Rail Electrification	3,737,049	3,107,406.1	1,257.3

[a] The analysis of potential GHG emission reductions is expressed in 100-year GWPs.
[b] Scenarios 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 scenarios ranked higher in the retrospective systems order.
Source: ADB. Forthcoming. *Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs.* Manila: ADB.

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

Table 27: Costs and Abatement Potentials for Pricing and Combined Mitigation Scenarios

Azerbaijan				
Scenario	**Cumulative Potential GHG Emission Reductions [a] [tCO_2e]**	**Percent Change by 2050 Compared to No Action Scenario (%)**	**Reduction Cost per Tonne [2007 AZN / tCO_2e]**	**Reduction Cost per Tonne [2010 $ / tCO_2e]**
Carbon Tax (Low)	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	575,454,155	-19.1	5.0	7.4
OECD Fuel Prices	1,103,806,342	-36.6	5.2	7.7
State Program of Poverty Reduction	-479,774,029	15.9	NA[b]	NA[b]
All Low-Cost Technical Measures	327,109,943	-10.8	-3.4	-4.9
All Moderate-Cost Technical Measures	359,753,652	-11.9	-0.9	-1.3
All Technical Measures	388,810,279	-12.9	15.2	22.3
Kazakhstan				
Scenario	**Cumulative Potential GHG Emission Reductions [a] [tCO_2e]**	**Percent Change by 2050 Compared to No Action Scenario (%)**	**Reduction Cost per Tonne [2010 KZT / tCO_2e]**	**Reduction Cost per Tonne [2010 $ / tCO_2e]**
Emissions Trading Scheme	1,544,370,058	-7.1	638.7	4.3
OECD Fuel Prices	1,124,925,667	-5.2	3,090.1	21.0
Extended ETS	1,558,672,146	-7.2	11,904.8	80.8
All Low-Cost Technical Measures	2,777,194,623	-12.9	768.4	5.2
All Technical Measures	2,916,074,370	-13.5	956.0	6.5
Uzbekistan				
Scenario	**Cumulative Potential GHG Emission Reductions [a] [tCO_2e]**	**Percent Change by 2050 Compared to No Action Scenario (%)**	**Reduction Cost per Tonne [2013 UZS / tCO_2e]**	**Reduction Cost per Tonne [2010 $ / tCO_2e]**
All Low-Cost Technical Measures	905,658,923	-6.5	-82,809.3	-33.5
All Technical Measures	1,069,661,249	-7.7	-42,404.2	-17.2

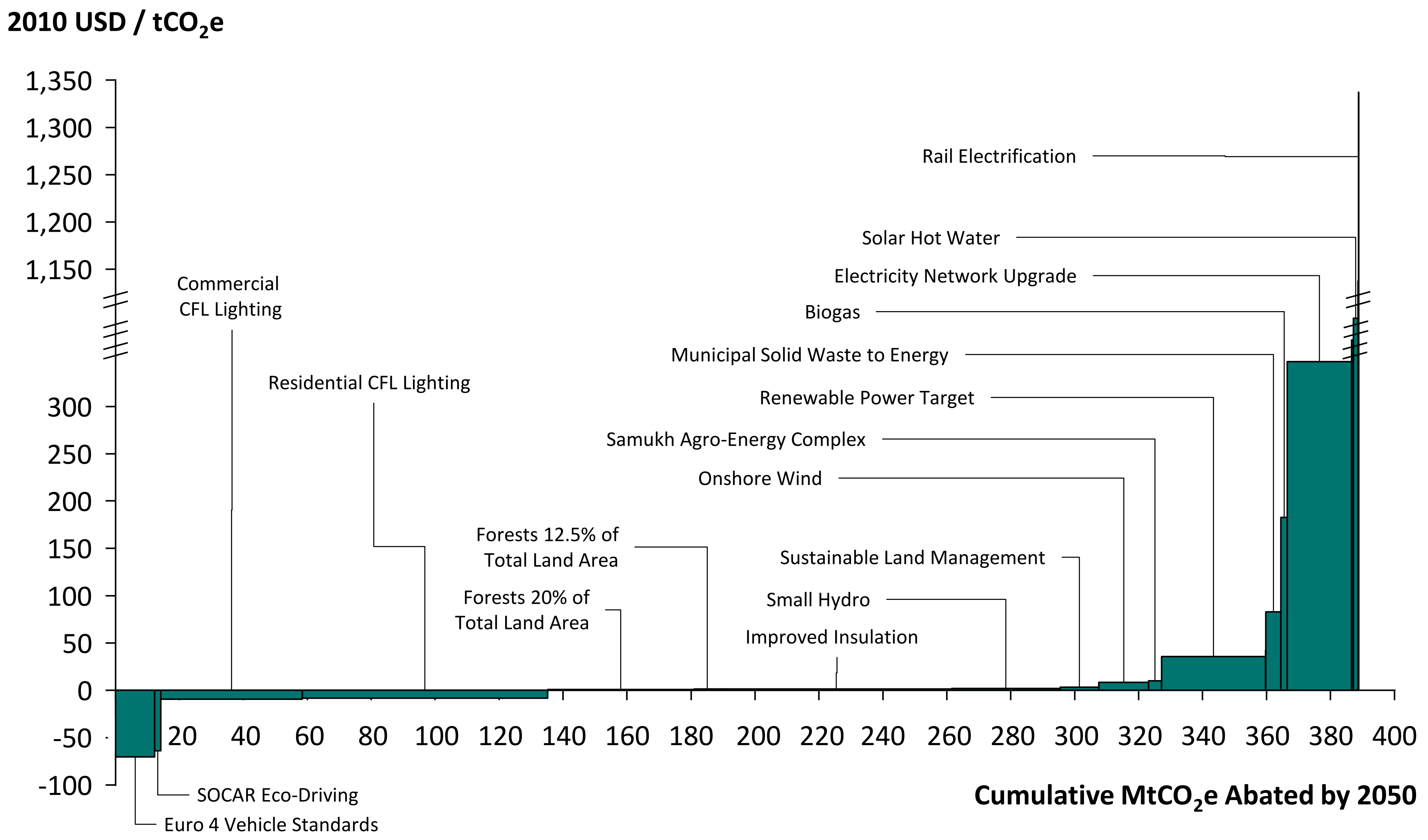
[a] The analysis of potential GHG emission reductions is expressed in 100-year GWPs.
[b] Scenarios marked "NA" have undefined abatement costs since they result in increased or unchanged emissions.
Source: ADB. Forthcoming. *Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs.* Manila: ADB.

5. Marginal Abatement Cost Curves

91. Abatement potentials and costs per tonne for the technical mini-scenarios can be represented visually in a *marginal abatement cost curve*, or MACC. A MACC is composed of a series of segments for the mitigation options that are explored—the width represents the total GHG abatement potential of an option, while the height describes the option's cost-effectiveness. Each segment is then aligned in order of increasing cost per tonne.

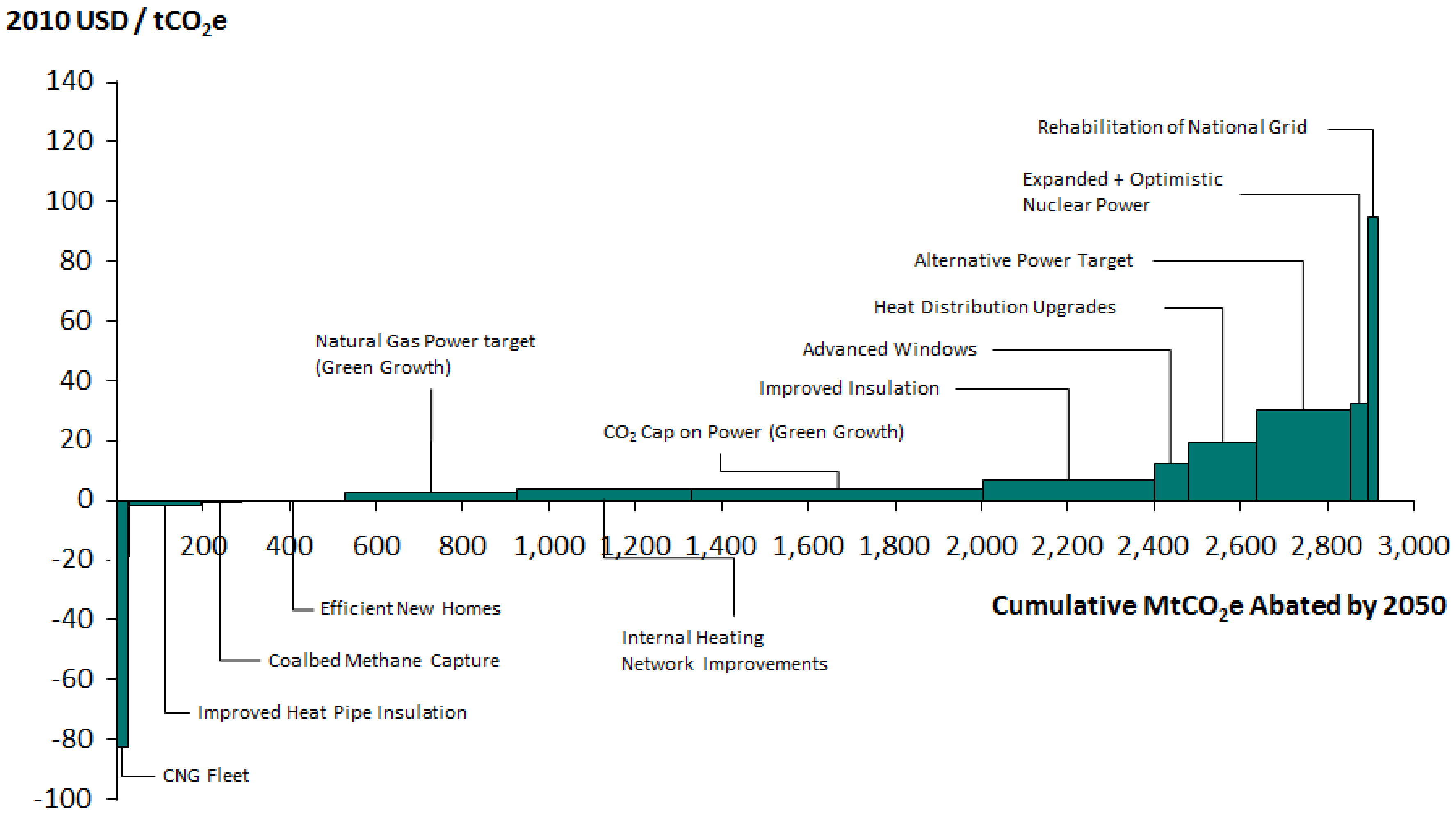
92. MACCs for Azerbaijan, Kazakhstan, and Uzbekistan follow in Figure 10 to Figure 11, displaying technical mitigation mini-scenarios only. Price-based mini-scenarios as well as combined mitigation scenarios cannot be considered together with the basic mini-scenarios due to the potential overlap in emission sources covered, and therefore cannot be represented on the same curve. For readability, mitigation options may be unlabeled on the curves below if their total mitigation potential is less than one-quarter of one percent of the potential from all options explored.

Figure 9: MACC of Technical Mitigation Scenarios in Azerbaijan



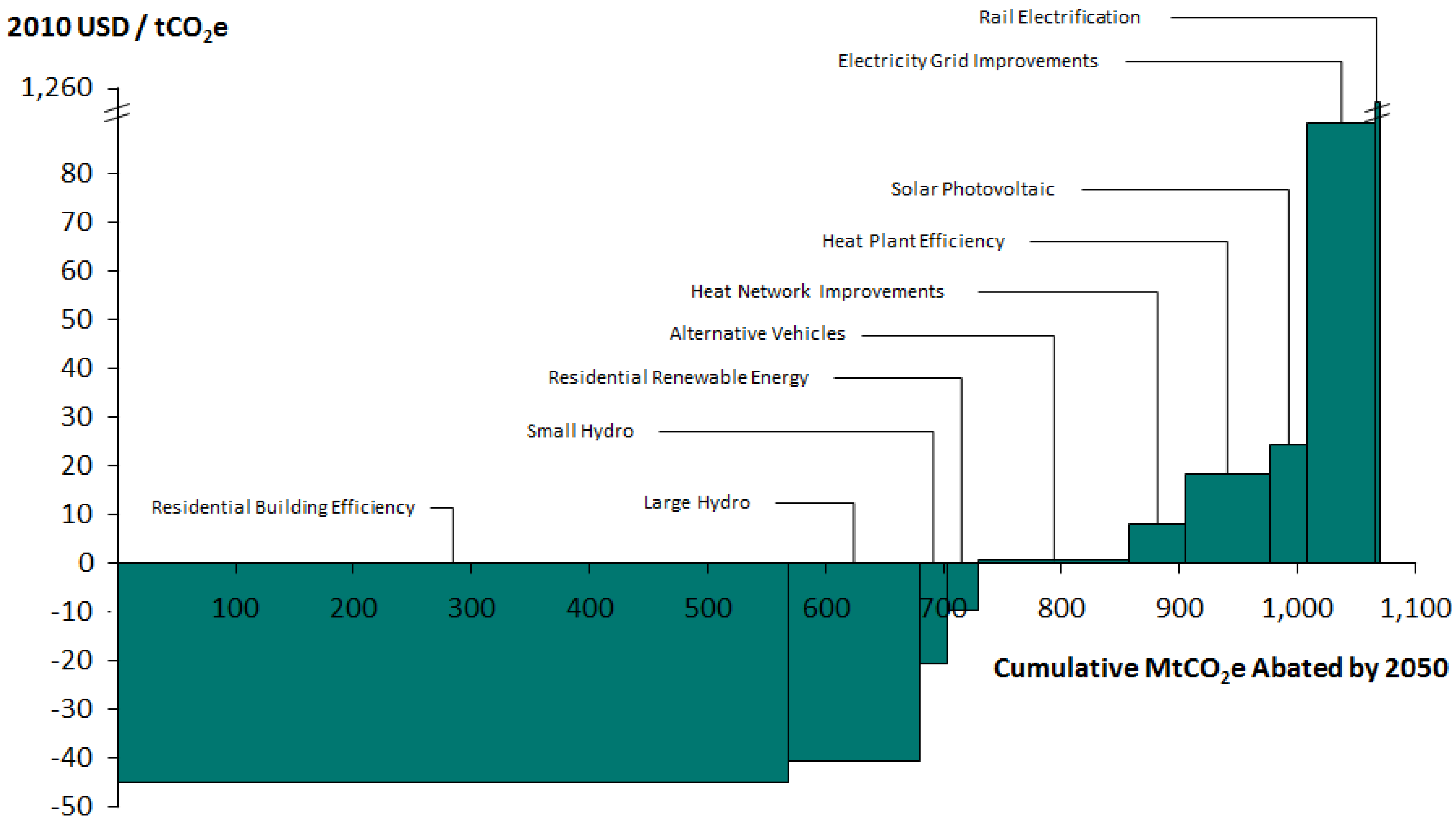
Source: ADB. Forthcoming. *Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs.* Manila: ADB.

Figure 10: MACC of Technical Mitigation Scenarios in Kazakhstan



Source: ADB. Forthcoming. *Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs.* Manila: ADB.

Figure 11: MACC of Technical Mitigation Scenarios in Uzbekistan



Source: ADB. Forthcoming. *Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs.* Manila: ADB.

93. The cost-benefit analysis indicates that in each country there is a selection of technical mitigation measures with high GHG abatement potential that can be accessed at either a direct cost savings or at a very low cost per tonne of abatement. These are particularly attractive measures, and include mandating Euro 4 vehicles, SOCAR Eco-driving, commercial and residential CFL lighting, small hydro in Azerbaijan; the introduction of CNG vehicles, improved heat pump insulation, coalbed methane capture, and efficient new homes in Kazakhstan; and both small and large hydro in Uzbekistan.

94. In addition, several low-cost measures in all three countries involve introduction of increased renewables such as solar, wind, and biomass. As discussed later in Section D, the proposed NAMAs to promote small hydro in Uzbekistan, CNG and energy efficiency in Kazakhstan, and renewable energy in Azerbaijan are intended to accelerate the deployment of these cost-effective mitigation options by removing some of the barriers to their implementation.

95. In Azerbaijan, the removal of subsidies represents a low-cost measure with a potential for very large emission reductions. In Kazakhstan, the natural gas power target, the alternative power target, a CO_2 cap on power generation, the 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, the government of Kazakhstan is moving ahead with the Green Growth Concept which establishes an overall framework for their implementation.

96. Many of the highest-cost measures analyzed in Table 26 contribute relatively little to the overall level of abatement that is achievable by the ensemble of mitigation options. However, some options with a high cost per tonne 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).

6. Human Health and Energy Security Co-benefits of Mitigation Options

97. This subsection summarizes the indirect co-benefits that can be achieved by implementing the mitigation options analyzed in this TA. The analysis focuses on those co-benefits for which data is readily available for quantifying impacts. These include reduced air pollutant emissions, human health benefits of reduced air pollution, and improved energy security. There are other potential benefits of mitigation such as income and employment generation. However, these are not quantified in this TA.

98. The analysis of human health co-benefits examines the benefits of mitigation measures that reduce both GHG and conventional air pollutant emissions from the electricity and transport sectors. These are expressed in terms of the potential health benefits of reduced air pollution (cumulative avoided mortalities from 2010 – 2050, compared to the *no action* scenario). Focusing on the health benefits in addition to GHG mitigation helps improve the overall benefits that may be derived from the mitigation options examined.

99. Increased energy security means that the energy system 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 co-benefits. Impacts on energy security from the mitigation options are expressed in comparison to the *no action* case. These metrics include:

(i) Fuel savings. This metric describes cumulative fuel savings from 2010 – 2050, expressed in million gigajoules of primary energy supply in LEAP;
(ii) Energy intensity. This metric describes the percentage change compared to the *no action* scenario in 2020 and 2050, and is expressed in terms of energy consumption per unit of GDP;
(iii) Carbon intensity. This metric describes the percentage change compared to the *no action* scenario in 2020 and 2050, and is expressed in terms of CO_2 emissions per unit of GDP; and
(iv) Percentage share of imports in total energy supply. This metric describes the percentage change in the renewable energy share compared to the *no action* scenario in 2020 and 2050.

100. Unlike the analysis of direct costs and benefits, the co-benefits analysis does not account for interactions and potential overlap between mitigation options. The impact of each mitigation option is analyzed relative to the *no action* scenario to isolate the effect of each particular option on human health and energy security. Table 28 - Table 30 summarize the results of the co-benefits analysis for Azerbaijan, Kazakhstan, and Uzbekistan, respectively.

101. Many of the mitigation scenarios analyzed result in cumulative avoided mortalities through 2050. For example, the OECD Fuel Price scenario in Azerbaijan results in 242 avoided mortalities. Similarly, the extended ETS scenario in Kazakhstan results in 5,825 avoided mortalities, and the All Mini-Scenarios option in Uzbekistan results in 489 avoided mortalities through 2050.

102. Table 28 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 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

103. Table 29 shows that the largest overall co-benefits in Kazakhstan are produced by the Extended Emission Trading Scheme, and the alternate version of the ETS. Public health benefits for these options are on 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

Table 28: Summary of Human Health and Energy Security Co-Benefits of Mitigation in Azerbaijan *(incremental impacts relative to the no action scenario only)*

Azerbaijan								
Mitigation Option	**Cumulative Incremental Avoided Mortalities**	**Cumulative Fuel Savings (million gigajoules)**	**Energy Intensity of GDP (percent change compared to no action scenario)**		**Carbon Intensity of GDP (percent change compared to no action scenario)**		**Renewable Energy Percentage in Primary Energy Supply (percent change compared to no action scenario)**	
	2010 – 2050	**2010 – 2050**	**2020**	**2050**	**2020**	**2050**	**2020**	**2050**
Technical Mitigation Mini-Scenarios								
Euro-4 Vehicle Standards	21.7	160.5	-0.30%	-0.90%	-0.30%	-0.90%	0.30%	0.90%
SOCAR Eco-driving	0.6	18.2	-0.10%	-0.10%	-0.10%	-0.10%	0.10%	0.10%
Commercial CFL Lighting	21.5	621.9	-1.10%	-3.20%	-1.00%	-3.00%	1.10%	3.30%
Residential CFL Lighting	35.9	1,032.4	-1.90%	-5.20%	-1.70%	-4.90%	1.90%	5.50%
Forests 20% of Total Land Area	0	-0.2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Forests 12.5% of Total Land Area	0	0.0	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Improved Insulation	10.7	985.6	-1.80%	-6.90%	-1.60%	-6.30%	1.80%	7.40%
Small Hydro	13.9	243.3	-1.00%	-0.30%	-1.40%	-0.50%	10.70%	8.30%
Sustainable Land Management	0	0.0	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Onshore Wind	5.6	125.1	0.00%	-1.40%	0.00%	-2.20%	0.00%	35.20%
Samukh Agro-Energy Complex	1.2	17.6	-0.10%	-0.10%	-0.30%	-0.20%	3.40%	4.50%
2020 Renewable Power Targets	17.8	338.4	-2.30%	-1.10%	-3.40%	-1.70%	28.10%	27.50%
3 MW Small Solar	0	0.7	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
Municipal Solid Waste to Energy	-13.7	-218.7	0.60%	1.70%	-0.20%	-0.40%	14.00%	76.40%
Biogas	0.8	25.4	-0.10%	-0.10%	-0.10%	-0.10%	0.00%	-0.20%
Electricity Network Upgrade	12.7	382.6	-0.80%	-2.60%	-0.70%	-2.40%	0.80%	2.70%
AC Rail Conversion	0.3	7.6	0.00%	-0.10%	0.00%	-0.10%	0.00%	0.10%
Solar Hot Water	0.2	19.9	0.00%	-0.10%	0.00%	-0.10%	0.00%	0.00%
Efficient Stoves	0	5.1	0.00%	0.00%	0.00%	0.00%	-0.10%	-0.60%

Azerbaijan								
Mitigation Option	Cumulative Incremental Avoided Mortalities	Cumulative Fuel Savings (million gigajoules)	Energy Intensity of GDP (percent change compared to no action scenario)		Carbon Intensity of GDP (percent change compared to no action scenario)		Renewable Energy Percentage in Primary Energy Supply (percent change compared to no action scenario)	
	2010 – 2050	2010 – 2050	2020	2050	2020	2050	2020	2050
Rail Electrification	0.1	-0.2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
SAARES Short-Term Plan	16	299.8	-2.30%	-0.20%	-3.40%	-0.30%	28.10%	4.50%
Pricing and Combined Mitigation Scenarios								
Carbon Tax (Low)	130.2	5,380.6	-11.10%	-36.90%	-12.20%	-38.30%	51.50%	260.80%
Carbon Tax (Moderate)	146.7	6,263.0	-14.00%	-42.10%	-14.90%	-43.20%	55.70%	286.70%
Carbon Tax (EU Harmonization)	154.5	6,671.1	-16.10%	-42.20%	-16.90%	-43.30%	59.10%	287.60%
Fossil Subsidy Removal	165.0	6,849.2	-13.70%	-37.90%	-14.30%	-40.70%	34.50%	267.50%
OECD Fuel Prices	242.2	14,369.6	-55%	-65%	-52.80%	-64.30%	153.30%	346.10%
State Program of Poverty Reduction	-43.5	-4,987.7	-9.40%	-25.70%	-5.40%	-23.90%	-5.80%	8.60%
All Low-Cost Technical Measures	109.6	3,353.1	-7.00%	-18.05%	-7.26%	-18.01%	24.90%	77.93%
All Moderate-Cost Technical Measures	128.3	3,644.6	-9.50%	-18.20%	-10.70%	-18.30%	54.10%	83.60%
All Technical Measures	119.8	3,783.2	-9.85%	-18.64%	-11.63%	-20.56%	69.38%	180.80%

Table 29: Summary of Human Health and Energy Security Co-Benefits of Mitigation in Kazakhstan *(incremental impacts relative to the no action scenario only)*

Kazakhstan								
Mitigation Option	Cumulative Incremental Avoided Mortalities	Cumulative Fuel Savings (million gigajoules)	Energy Intensity of GDP (percent change compared to no action scenario)		Carbon Intensity of GDP (percent change compared to no action scenario)		Renewable Energy Percentage in Primary Energy Supply (percent change compared to no action scenario)	
	2010 – 2050	2010 – 2050	2020	2050	2020	2050	2020	2050
Technical Mitigation Mini-Scenarios								
CNG Fleet	3.4	470	-0.60%	0.00%	0.00%	0.20%	0.80%	0.00%
CNG Passenger Cars	0.1	25	0.00%	0.00%	0.40%	0.20%	0.00%	0.00%
Improved Heat Pipe Insulation	0	1,604	0.00%	-1.00%	0.40%	-1.00%	0.00%	1.00%
Coalbed Methane Capture	-1.8	122	0.00%	0.00%	0.40%	0.20%	-1.20%	0.00%
Efficient New Homes	0	2,307	-1.20%	-1.30%	-1.00%	-1.30%	1.20%	1.30%
Natural Gas Power Target (Green Growth)	634.2	1,508	0.10%	-1.40%	0.40%	-4.50%	-0.10%	10.20%
Internal Heating Network Improvements	0	3,906	0.00%	-2.50%	0.40%	-2.80%	0.00%	2.60%
CO_2 Cap on Power (Green Growth)	1,152.30	1,907	-0.20%	-1.30%	-4.00%	-14.80%	31.80%	29.40%
Improved Insulation	0	3,992	0.00%	-2.60%	0.40%	-2.90%	0.00%	2.70%
Advanced Windows	0	838	0.00%	-0.50%	0.40%	-0.40%	0.00%	0.50%
Heating Distribution Upgrades	0	3,261	-0.70%	-2.00%	-0.50%	-2.10%	0.70%	2.00%
Alternative Power Target	278	2,204	0.10%	-3.50%	0.40%	-10.90%	-0.10%	397.80%
Expanded Nuclear Power	361.7	136	0.10%	0.10%	0.40%	-0.20%	0.20%	-0.10%
Optimistic Nuclear Power	884.4	302	0.00%	0.20%	0.40%	-0.40%	0.50%	0.20%
Rehabilitation of National Grid	-4	366	0.10%	-0.30%	0.40%	-0.20%	-0.80%	0.30%
Urban LED Lighting	-0.3	14	0.10%	0.00%	0.40%	0.20%	-0.10%	0.00%
Waste to Energy	-6.4	-35	0.10%	0.10%	0.40%	0.20%	0.30%	4.60%
Euro 5 Vehicles	-2.4	-149	0.00%	0.10%	0.40%	0.30%	0.00%	-0.10%

Kazakhstan								
Mitigation Option	Cumulative Incremental Avoided Mortalities	Cumulative Fuel Savings (million gigajoules)	Energy Intensity of GDP (percent change compared to no action scenario)		Carbon Intensity of GDP (percent change compared to no action scenario)		Renewable Energy Percentage in Primary Energy Supply (percent change compared to no action scenario)	
	2010 – 2050	2010 – 2050	2020	2050	2020	2050	2020	2050
Early Vehicle Retirement	8.7	-148	0.20%	0.10%	0.60%	0.30%	-0.20%	-0.10%
Pricing and Combined Mitigation Scenarios								
Emissions Trading Scheme	5,581.5	3,675	-6.10%	0.00%	-13.40%	-2.60%	37.40%	5.90%
Extended ETS	5,826.1	2,320	-5.70%	0.90%	-14.90%	-1.50%	36.90%	17.00%
OECD Fuel Prices	283.2	15,584	-3.90%	-12.40%	-1.20%	-11.10%	9.20%	-1.10%
All Low-Cost Technical Measures	2,070.4	14,289	-3.09%	-6.81%	-4.96%	-24.77%	49.20%	55.59%
All Technical Measures	3,109.4	16,945	-2.59%	-7.72%	-4.86%	-25.49%	40.65%	68.60%

Table 30: Summary of Human Health and Energy Security Co-Benefits of Mitigation in Uzbekistan *(incremental impacts relative to the no action scenario only)*

Uzbekistan								
Mitigation Option	**Cumulative Incremental Avoided Mortalities**	**Cumulative Fuel Savings (million gigajoules)**	**Energy Intensity of GDP (percent change compared to no action)**		**Carbon Intensity of GDP (percent change compared to no action)**		**Renewable Energy Percentage in Primary Energy Supply (percent change compared to no action)**	
	2010 – 2050	**2010 – 2050**	**2020**	**2050**	**2020**	**2050**	**2020**	**2050**
Technical Mitigation Mini-Scenarios								
Residential Building Efficiency	39.0	9,686	-3.69%	-8.90%	-3.87%	-9.37%	3.07%	7.19%
Large Hydro	155.0	898	-0.47%	-0.47%	-1.04%	-1.02%	24.38%	24.49%
Small Hydro	24.5	181	-0.11%	-0.08%	-0.24%	-0.20%	5.46%	5.81%
Residential Renewable Energy	25.6	846	-0.18%	-0.85%	-0.21%	-0.83%	-0.07%	-1.80%
Alternative Vehicles	146.0	1,882	-0.60%	-1.87%	-0.71%	-2.29%	0.62%	1.97%
Heat Network Improvements	0.0	776	-0.05%	-1.05%	-0.06%	-1.17%	0.05%	1.06%
Heat Plant Efficiency	0.0	1,206	-0.21%	-1.17%	-0.23%	-1.30%	0.21%	1.19%
Solar Photovoltaic	42.9	270	-0.13%	-0.16%	-0.28%	-0.34%	6.71%	8.41%
Electricity Grid Improvements	52.4	1,085	-0.31%	-0.97%	-0.37%	-0.94%	-0.28%	-3.53%
Rail Electrification	22.2	22	0.00%	-0.01%	0.00%	-0.03%	0.04%	0.19%
Pricing and Combined Mitigation Scenarios								
All Low-Cost Technical Measures	379.2	13,874.6	-5.03%	-12.66%	-5.98%	-14.34%	34.52%	44.54%
All Technical Measures	489.0	16,350	-5.64%	-14.85%	-6.77%	-16.83%	40.83%	53.00%

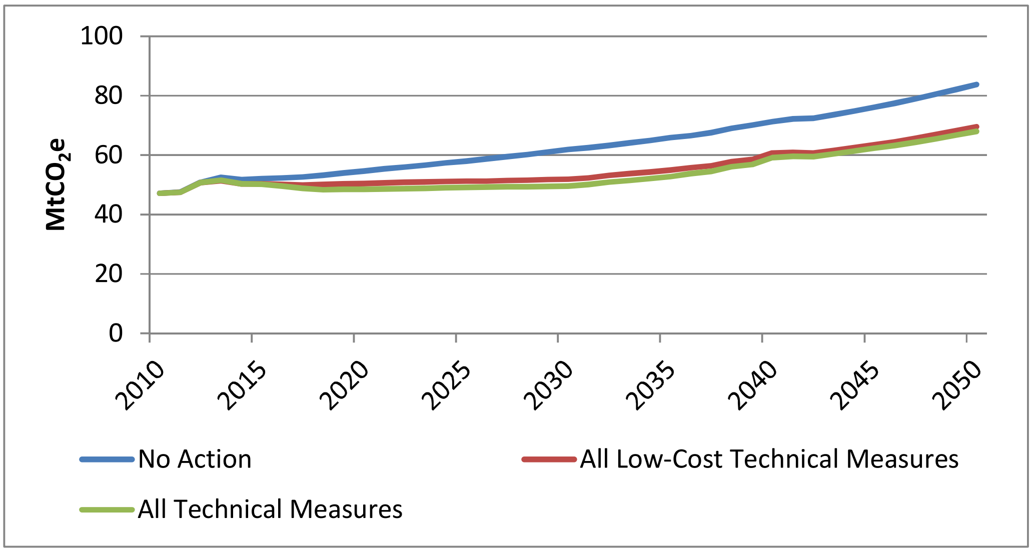
options produce few human health benefits, and have mixed or lower benefits for energy security overall. For example, the Natural Gas Power Target scenarios show improvements in energy security over the long-run, by 2050, but show increases in energy and carbon intensity and a reduction of renewable energy use in the short-run, by 2020.

104.The results for Uzbekistan (Table 30) indicate the largest co-benefit effects arise from the All Mini-Scenarios 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 Hydro and Alternative Vehicle options produce the most significant co-benefits. Both of these options have similar health effects (about 150 avoided mortalities), but Large Hydro has larger benefits for energy security. None of the mitigation options for Uzbekistan result in increases in air pollutant-related mortalities.

7. Policy Implications of the Mitigation Analysis

105. Figure 12 through 14 and Table 31 through Table 33 show the overall effect of the study's mitigation options on GHG emissions. Two groups of options are depicted for each country—low-cost options whose cumulative (through 2050) discounted cost per tonne of CO_2e abated is less than or equal to 10 2010 US$, and all options evaluated. The *no action* projections are also shown.

Figure 12: Impact of Mitigation Options on GHG Emissions in Azerbaijan



Source: ADB. Forthcoming. *Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs.* Manila: ADB.

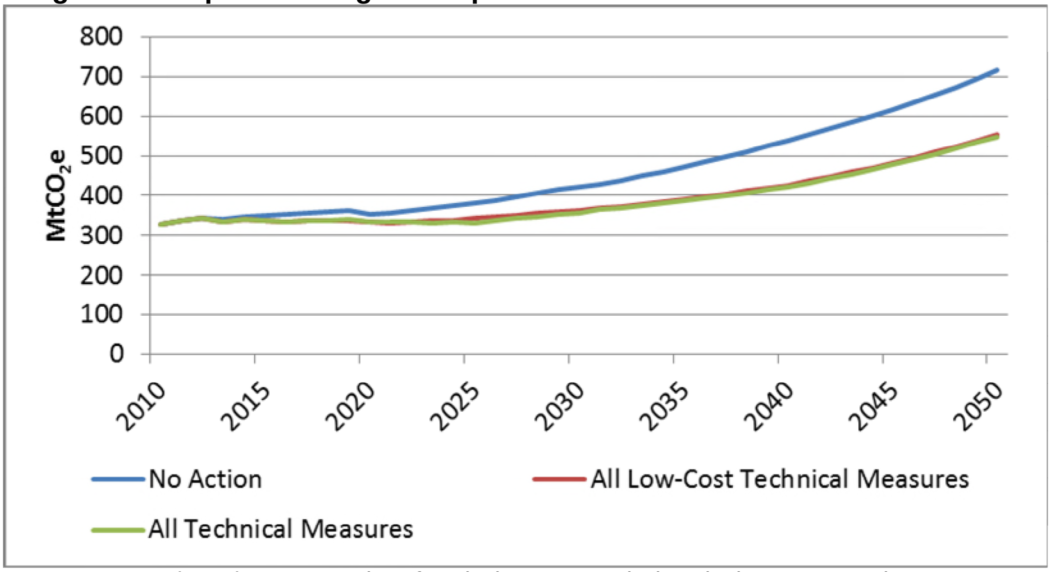
106. The portfolio of technical mitigation options for Azerbaijan and Kazakhstan results in significant abatement (around 20% versus the *no action* scenario), while the smaller set of options for Uzbekistan result in about 10% abatement. Most of the mitigation potential found in each country is low cost or result in overall savings to the country. For example, implementing all the low-cost technical measures analyzed for Azerbaijan and Uzbekistan can be done at a social cost of $ -4.9 tCO_2e and $ 17.9 tCO_2e, respectively. Adding the higher cost options that were analyzed provide only modest abatement gains. One reason for this result is that national plans and sources in the three countries prioritize cost-effective mitigation measures.

Table 31: Impact of Mitigation Options on GHG Emissions in Azerbaijan ($MtCO_2e$)

	2010	2020	2030	2040	2050
No Action	47.1	54.6	61.8	71.3	83.8
Low Cost Options	47.1	50.5	51.9	60.8	69.7
All Options	47.1	48.5	49.6	59.2	68.0

Source: ADB. Forthcoming. *Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs.* Manila: ADB.

Figure 13: Impact of Mitigation Options on GHG Emissions in Kazakhstan



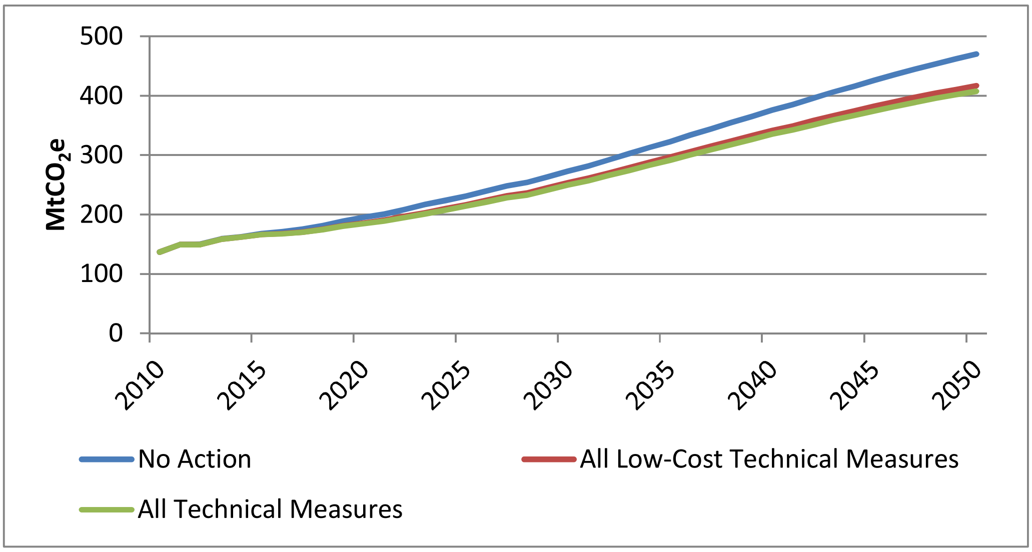
Source: ADB. Forthcoming. *Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs.* Manila: ADB.

Table 32: Impact of Mitigation Options on GHG Emissions in Kazakhstan ($MtCO_2e$)

	2010	2020	2030	2040	2050
No Action	328.6	352.0	422.9	538.0	715.7
Low Cost Options	328.6	333.0	362.8	426.3	552.2
All Options	328.6	333.3	357.2	421.7	547.6

Source: ADB. Forthcoming. *Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs.* Manila: ADB.

Figure 14: Impact of Mitigation Options on GHG Emissions in Uzbekistan



Source: ADB. Forthcoming. *Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs.* Manila: ADB.

Table 33: Impact of Mitigation Options on GHG Emissions in Uzbekistan ($MtCO_2e$)

	2010	2020	2030	2040	2050
No Action	137.0	195.1	273.2	375.9	469.9
Low Cost Options	137.0	185.9	253.7	341.3	416.6
All Options	137.0	184.7	249.8	334.9	407.4

Source: ADB. Forthcoming. *Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs.* Manila: ADB.

107. 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 Organization 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 fairly low cost to society of about \$ 7 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.

108. 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 (12.9%). 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.

109. In Azerbaijan and Kazakhstan, 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. Total emissions are greater in 2050 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. In Uzbekistan, the energy efficiency and renewable energy measures analyzed in this TA 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.

110. Significantly slowing the increase in long-run emissions (i.e., 2030-2050) requires rethinking of energy use for buildings, industry, and transport by pushing efficiency further than currently modeled. It also requires switching to low-carbon sources such as electricity, biofuels, and hydrogen; introduction of a meaningful carbon price; and integrated land use planning in urban areas to reduce vehicle and passenger miles. Additional de-carbonization of the power sector is likely necessary. These changes are doubly important if Azerbaijan, Kazakhstan, and Uzbekistan are to contribute to a global 2˚ C scenario. Such pathways will be more costly and very ambitious, however, and may only be feasible if supporting international finance and technical cooperation is available.

C. Capacity Development for Cost Benefit Analysis of Mitigation (Output 1)

111. In support of the cost benefit analysis of mitigation options in the energy and transport sectors, the TA included a capacity development program aimed at training decision makers in economic analysis of low carbon growth measures and policy, and strengthening national systems for GHG emission monitoring, verification, and reporting.

112. The capacity building program was implemented through a series of workshops, which are presented in Table 34 on the following page. To date 254 national decision makers have been trained during two regional and four national workshops. Of these, women represent 89 (or 35%) of the experts trained. One-day national inception workshops were also held in Azerbaijan and Kazakhstan in January 2014, but these focused on stakeholder consultations and not training. As a result, they are not counted in Table 34.

113. The capacity development program included one regional and three national workshops to train national decision makers on the use of LEAP for analyzing the costs and benefits of mitigation. The first workshop, which was regional, was held in Astana, Kazakhstan in November 2013 before the national models had been fully developed. Workshop participants engaged actively in the exercises and resulting discussions, often linking exercises to actual examples from their own countries. On several occasions, participants exchanged information on work done and policies implemented in their individual countries, since most had not worked directly with each before.

Table 34: Capacity Development Activities to Support Economic Analysis of Mitigation and GHG Emissions Accounting, Monitoring, and Reporting

Workshop/Training	Location	Date	Training Content	Number of Participants (Women)
5-day regional training on using LEAP for economic analysis of mitigation	Astana, KAZ	November 2013	Basic theories and practical techniques for conducting cost-benefit analysis of mitigation and constructing a MAC curve Estimating, tracking, and reporting GHG emissions from mitigation measures	22 (11)
2-day regional interim regional workshop on NAMA readiness and investment for mitigation	Astana, KAZ	June 2014	Evaluation, design, and finance of NAMAs and mitigation measures Monitoring, reporting, and verification of mitigation options	36 (15)
1-day national inception workshop in Uzbekistan	Tashkent, UZB	October 2014	Introduction of TA 8119 and training on NAMAs and climate finance Monitoring, reporting, and verification of mitigation measures	21 (6)
5-day national interim workshop and LEAP training in Azerbaijan	Baku, AZE	November 2014	Theories and practical techniques for conducting cost-benefit analysis of mitigation using the national model for Azerbaijan Estimating, tracking, and reporting GHG emissions from mitigation measures	19 (8)
4-day national interim workshop and LEAP training in Kazakhstan	Astana, KAZ	December 2014	Theories and practical techniques for conducting cost-benefit analysis of mitigation using the national model for Kazakhstan Estimating, tracking, and reporting GHG emissions from mitigation measures	14 (7)
5-day national interim workshop and LEAP training in Uzbekistan	Tashkent, UZB	March 2015	Theories and practical techniques for conducting cost-benefit analysis of mitigation using the national model for Uzbekistan Estimating, tracking, and reporting GHG emissions from mitigation measures	18 (9)
1-day national final workshop in Uzbekistan	Tashkent, UZB	July 2015	Present final results of TA 8119 Monitoring, reporting, and verification	28 (8)
1-day national final workshop in Kazakhstan	Astana, KAZ	July 2015	Present final results of TA 8119 Monitoring, reporting, and verification	37 (14)
1-day national final workshop in Azerbaijan	Baku, AZE	July 2015	Present final results of TA 8119 Monitoring, reporting, and verification	23 (3)
2-day regional final workshop in Azerbaijan	Baku, AZE	July 2015	Design and financing of NAMAs and other mitigation options Monitoring, reporting, and verification of mitigation options	36 (8)
			Total Number of Decision Makers Trained	**254 (89)**

Source: Abt Associates, RETA 8119 workshop summaries.

114. Noting the strong interest by stakeholders in receiving further training in the national models to be developed under the TA, the remainder of the training program for the economic analysis was arranged to coincide with the interim national workshops.

115. The national interim workshops and LEAP trainings were held in Azerbaijan and Kazakhstan in Fall 2014 and in Uzbekistan in Spring 2015 to coincide with the release of draft national models for each country. During the workshops, stakeholders were asked to review key results, assumptions, and data sources used, as well as participate in training on the LEAP models. This approach obtained valuable feedback on model design and the cost data used for evaluating individual mitigation options. The national trainings were well-received and participants engaged actively throughout all the exercises. Many participants requested further training with additional hands-on exercises focusing on renewable and clean energy, and using other countries as case studies for training exercises.

Figure 15. Participants Conduct a LEAP Exercise in Azerbaijan

D. Design of National Appropriate Mitigation Actions (NAMAs) (Output 2)

116. In addition to assessing the costs and benefits of mitigation, a second output of the TA is to formulate NAMAs and identify climate change mitigation investment opportunities in the energy and transport sectors of Azerbaijan, Kazakhstan, and Uzbekistan.

117. The term NAMA, introduced as part of the international negotiations under the UNFCCC, refers to an action that reduces GHG emissions in developing countries and is prepared under the umbrella of a national government initiative. NAMAs can be policies directed at transformational change within an economic sector, or actions across sectors for a broader national focus.[25] NAMAs were first mentioned 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." The term was later clarified in the 2010 Cancun Decision, which specified 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 GHG emissions reductions that are measured, reported, and verified.

118. The international community did not further specify what form NAMAs should take. Since then, international NAMA support programs—such as the NAMA Facility funded by the

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

governments of Denmark, Germany, and the United Kingdom and the Spanish NAMA Facility—have provided more detail on the expectations for NAMA design.

119. Four NAMA concept notes were developed under the TA for Azerbaijan, Kazakhstan, and Uzbekistan and were selected in consultation with government counterparts and other stakeholders in each country. The NAMA concepts were formulated as stand-alone write-ups that each government can use for their individual needs. For example, they can submit the NAMA concept to the UNFCCC NAMA Registry[26] which facilitates matchmaking between planned NAMAs and funding sources. The national governments can also submit the NAMA concepts directly to a potential international partner for further development into a proposal for financial, technical, or capacity building support. Alternatively, Azerbaijan, Kazakhstan and Uzbekistan may choose to implement these NAMAs unilaterally without international support. The NAMA concepts developed under this TA are ready for submission to the UNFCCC NAMA Registry.[27]

120. The NAMA concepts developed under this TA include the following:

(i) Promoting agro-energy development based on renewable energy in Azerbaijan;
(ii) Fostering use of natural gas in the transport sector in Kazakhstan;
(iii) Developing a national energy efficiency support system in Kazakhstan; and
(iv) Accelerating deployment of small-scale hydro in Uzbekistan.

121. The selection of the four NAMAs was informed by consultations conducted during workshops and meetings with individual stakeholders. The most important factor in their selection, beyond contribution to avoiding GHG emissions, was their close fit with national development priorities. Another key factor in their selection includes the commitment and willingness of individual stakeholder agencies to engage in the NAMA process and provide the information necessary for their development.

122. Finally, as illustrated in Table 35 the mitigation options selected for NAMAs were found to have no or very little cost per tCO_2e abated and are therefore attractive from a perspective of social benefits. The NAMA to foster use of natural gas for transport in Kazakhstan (-82.6 $/tCO$_2$e) and the NAMA to accelerate small-scale hydropower in Uzbekistan (-20.7 $/tCO$_2$e) both result in cost savings to society. The NAMA to promote agro-energy development based on renewable energy in Azerbaijan is low cost (10 $/tCO$_2$e) and results in important energy security and rural development benefits. Similarly, the NAMA to develop an energy efficiency support system for Kazakhstan targets a range of negative or low cost measures (-2 to 19.5 $/tCO$_2$e) that can result in considerable fuel savings to the country.

[26] The UNFCCC Secretariat established the NAMA Registry in 2013 to foster mitigation actions in developing countries and provide a platform for recognizing national mitigation actions. The Registry tracks NAMAs that are seeking international support and provides information on international funding for such mitigation actions. The NAMA Registry. 2015. http://unfccc.int/cooperation_support/nama/items/7476.php
[27] The NAMA Registry. 2015. http://unfccc.int/cooperation_support/nama/items/7476.php

Table 35: Proposed NAMA 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	Developing a National Energy Efficiency Support System	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.	Creates an online system for tracking energy efficiency improvements, pilots its use, and expands it to include energy efficiency in the transport sector.	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	1,607 annual direct reductions Indirect reductions to be determined	918,715 annually by 2030
Time Period [a]	2014–2020	2014-2025	2015-2025	2015-2030
Cost of implementation (Million $) [a]	277.9	74.1	3.5	728.7
Average Cost of GHG Abatement [b] (2010 $/$tCO_2e$)	10	-82.6	(-2) to 19.5 Depends on the type of efficiency improvement	-20.7

Sources:
[a] ADB. *Report on Nationally Appropriate Mitigation Actions (NAMAs) in Azerbaijan, Kazakhstan, and Uzbekistan.* Manila. August 2015.
[b] ADB. Forthcoming. *Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs.* Manila: ADB.

123. The four NAMA concepts are summarized in Table 35 and are described in more detail in a separate document prepared under the TA, *Report on Nationally Appropriate Mitigation Actions (NAMAs) in Azerbaijan, Kazakhstan, and Uzbekistan.* This report also provides the status of NAMA design and institutions in Azerbaijan, Kazakhstan and Uzbekistan and presents information on the methods used to evaluate and design the NAMA concepts under the TA.

124. The subsections below briefly summarize the contents of the proposed NAMA concepts.

1. Promoting Agro-Energy Development Based on Renewable Energy in Azerbaijan

125. The design and implementation of this NAMA will be led by SAARES, a government agency established in 2010 to implement state policy on renewable energy, develop the infrastructure for renewable energy, oversee adoption of renewable energy in all sectors of the economy, and track and report on renewable energy activities.

126. The government of Azerbaijan has adopted several strategies and goals to promote renewable energy. The State Programme on Utilization of Renewable and Alternative Sources of Energy (2008–2015) set a 20% alternative and renewable energy target by 2020; the government established SAARES to achieve these goals for increasing alternative and

renewable energy sources and diversify the economy. In 2011, the President issued a new order setting a target for alternative and renewable energy and directing SAARES to develop a strategy for how to meet this. The target specifies that 20% of electricity consumption by 2020 must come from electricity generated from renewable energy sources. Also by 2020, 9.7% of total energy consumption must be met by renewable energy sources, and 2,000 MW of renewable energy capacity must be installed.[28]

127. In December 2014, SAARES released its strategic plan for 2015-2018, which 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, by 2018 SAARES will construct the following facilities: wind facilities providing 187 MW capacity, solar facilities providing 369 MW, bioenergy facilities providing 63 MW, and hydropower providing 116 MW. Altogether, the plan will result in 735 MW of new alternative and renewable energy supply.[29] To further support the implementation of renewable energy, SAARES is studying development of a new tariff methodology for renewable and alternative energy, and a new tariff will be set for solar power by end of 2015.

128. 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 helps accelerate the adoption of renewable energy in the agricultural sector. The NAMA is designed to address barriers to renewables by working with the government to reform the legal and regulatory norms governing renewable energy, including revising the tariff structure, proposing incentives for importation and production of relevant equipment and spare parts, and establishing a preferential loan program.

129. The NAMA will also support the construction and implementation of the Samukh Agro-Energy Residential Complex—a modern renewable energy–powered agriculture and food processing center, integrated in one campus with public and residential facilities and operating as close to carbon-neutral and waste-free as possible. The Samukh Complex will include several lines of agricultural production, such as grain and vegetable plantations, greenhouses, fruit orchards, cattle breeding, dairy farms, fisheries, and juice, fruit and livestock feed packaging factories. In addition to the agricultural facilities, up to 1,000 residential units will be constructed to house workers and refugees from the Nagorno-Karabakh region.

130. The complex will be powered by a variety of renewable sources for electricity and heat generation, including solar, geothermal, and locally produced biomass waste generated from the Complex's own operations or collected from the nearby region. Although Azerbaijan has a small but growing number of agricultural enterprises, this would be the first such complex to be powered by renewable energy. As part of the NAMA, SAARES will use the lessons learned and the technical skills gained from the Samukh Complex to replicate it at five other locations in Azerbaijan and, through successful implementation, encourage other agricultural enterprises to adopt renewable energy at their production facilities.

[28] Order of the President of Republic of Azerbaijan on preparation of National Strategy on the use of alternative and RES for 2010-2020.

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

131. Feasibility studies are still ongoing to determine the final arrangement for the proposed agro-energy residential complex at Samukh and other sites in Azerbaijan. The activities described below are currently envisioned, which may be modified pending results of the feasibility studies.

132. Phase 1 (2014–2016):
Phase 1 focuses on feasibility assessment and design and construction of the first set of facilities at Samukh, including the following:

(i) Development of 14.1 MW of installed electricity and heat capacity from renewable energy sources. The energy will be used by agricultural ventures which will be constructed in parallel on 6,500 hectares;
(ii) Construction of energy-efficient homes for 350-500 individual families;
(iii) By 2015, preparation of proposals to the government on preferential loans for renewable energy;
(iv) Preparation of tariff proposals for alternative and renewable energy sources by 2016;
(v) Analyze specific processes in agricultural and food production that can benefit from renewable energy and prepare suggestions for realizing the identified benefits within the Samukh Complex and replicating these at other sites; and
(vi) Complete feasibility studies for establishing similar agro-renewable energy complexes at sites in Nakhchivan, Gadabav, Neftchala, Balakan, and Oghuz.

133. Phase 2 (2017–2020):
The activities at Samukh will be expanded using lessons learned from Phase 1. Phase 2 will encompass development of an additional 21.25 MW of electric and 41.65 MW of heat generating capacity from renewable energy at the Samukh pilot site. The agricultural and residential parts of the Complex will also be enlarged.

134. SAARES will review lessons learned from the Samukh Complex during Phase 1 and develop a plan for how to replicate these to five other sites. In 2014, agriculture and residential sectors consumed 0% of heat generation and 6.1% of electricity generation, and residential buildings consumed 68% of heat generation and 45.1% of electricity generation.[30] Given the heavy reliance on fossil fuels in the heat and electricity sectors in Azerbaijan, the introduction of renewables can lead to significant GHG abatement.

135. By 2020, the implementation of the NAMA will lead to cumulative direct reductions in GHG emissions of 346,104 tCO_2e by replacing electricity and heat generation from mostly fossil fuels at the Samukh pilot site. If the Samukh Agro-Energy Residential Complex is successful and leads to replication at five other sites, and assuming these complexes are of similar size, the potential *additional* emission reductions can be roughly estimated at 584,125 tCO_2e per year by 2020. The potential indirect reductions that will be achieved by changing the tariffs and other incentives for renewables are not assessed in this NAMA.

136. The total expected implementation cost is $ 277.9 million. Total international support requested by SAARES is $ 165 million.

[30] ADB. Forthcoming. *Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs*, Manila.

2. Fostering Use of Natural Gas in the Transport Sector of Kazakhstan

137. The design and implementation of this NAMA will be led by JSC KazTransGas, a state-owned natural gas production and supply operator in Kazakhstan.

138. The priority measures of the government's 2013 *Concept of Transition of the Republic of Kazakhstan to a Green Economy*[31] and the territorial development programs for the transport sector include the transition to natural gas in vehicles. The goal is to minimize the impact of urban/regional transport on the environment and public health and reduce dependence on more expensive and often imported fuels. The development of natural gas infrastructure is also a specific requirement of the "Governmental Program of Development and Integration of Transport Infrastructure of the Republic of Kazakhstan until 2020"[32].

139. CNG is much cheaper than gasoline and diesel, and the price is much more stable than that of oil-based fuels. With its low cost, CNG provides an attractive alternative for many vehicle applications if the necessary engine technologies and infrastructure to support refueling are available. This is particularly the case for operators of large fleets, such as municipal buses, trucks, and taxis.

140. This NAMA will support the government's goal of increasing the use of Kazakhstan's cheap and clean natural gas for transport, first by developing the infrastructure for supplying CNG throughout the country and later by developing the infrastructure for liquefied natural gas (LNG). JSC KazTransGas will: (i) construct a network of 35 to 100 CNG-fueling stations (CNGFS), (ii) create other infrastructure to enable a natural gas market in Kazakhstan (i.e., workshops for converting existing vehicles to CNG, testing and certification centers, training facilities), and (iii) extend natural gas to non-traditional transport areas.

141. The NAMA will enable investment in specific sites and projects, as well as 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. The NAMA will be implemented from 2014 to 2025.

142. The NAMA envisages 34 distinct activities that can be grouped into four main phases:

(i) Phase 1 (2014–2015): Pilot market infiltration;
(ii) Phase 2 (2016–2018): Extending use of natural gas in transportation to medium and small commercial players;
(iii) Phase 3 (2019–2020): Fuel switching in agriculture, construction, and other specialty vehicles; and
(iv) Phase 4 (2021–2025): Comprehensive market penetration.

143. Work on the program has already begun, mainly focusing on a wide range of regulatory barriers, including technical norms and standards that must be updated to reflect current CNG refueling equipment, conversion techniques, and vehicles.

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[31] The 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

[32] Presidential Decree No. 725 dated 13 January 2014, www.mid.gov.kz/images/stories/contents/gp_150520141656.pdf

144. Direct GHG emission reductions from this NAMA are estimated to range from 135,315 tCO_2e per year with no support from the international community to 1,766,574 tCO_2e per year by 2025 with a fully supported NAMA.

The total implementation cost is $74.1 million. JSC KazTransGas requests $49.3 million in international support for items such as constructing CNG infrastructure, supporting vehicle conversions, establishing training facilities, and conducting feasibility studies.

3. Developing a National Energy Efficiency Support System for Kazakhstan

145. This NAMA will be implemented by JSC Institute of Power Development and Energy Saving[33] (formerly JSC Kazakhenergoexpertiza), which is a subordinate institution of the Ministry of Investment and Development.

146. The NAMA supports the government's efforts to encourage and incentivize adoption of energy efficiency measures across all sectors of the economy by improving the infrastructure for tracking, reporting, and evaluating progress on energy efficiency measures. This will be accomplished by upgrading and enhancing the existing State Energy Registry of Kazakhstan (SER) and expanding it into an Energy Efficiency Support System (EESS)—a user-friendly, web-based knowledge management platform. The EESS will improve the compliance of SER subjects with Kazakhstan's Energy Efficiency Law and will provide state decision makers, the private sector, and other end users with technical and financial information and tools to facilitate implementation of specific energy efficiency improvement projects. Additionally, it will enable the Government of Kazakhstan to better measure and report on energy activity in both public and private sectors, facilitating Kazakhstan's shift towards a low-carbon development path that has the potential to be replicated throughout Central Asia. The resulting improvement in energy efficiency will avoid the combustion of fossil fuel for electricity and heat generation.

147. The NAMA will be implemented from 2015 to 2025 in four phases.

Phase 1. Upgrade the existing State Energy Registry (SER) to an automated on-line database with proper front- and back-end in order to improve data reporting, collection and analysis.

Phase 2. Expand the information collected by SER to cover additional sectors/technologies, like transport, that are not currently under its mandate.

Phase 3. Create a comprehensive web-based knowledge platform that provides state decision makers, business community, and end users with actionable information on energy efficiency and best practices to implement demand side management (EESS).

Phase 4. Add to the existing knowledge platform a marketplace of energy efficiency-related goods and services, such as contact information for available ESCOs and consulting companies, searchable database of offers from equipment suppliers or bidding venue for energy services providers. Conduct one to two pilot projects in one of the oblasts to test the effectiveness of the support provided by EESS for project implementation.

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[33] See the organization web site at http://www.kazee.kz/ .

148. Implementation of Phase 1 is estimated to reduce direct GHG emissions by 1,607 tCO_2e per year.

149. The total implementation cost of the NAMA is $3,552,800. $2,730,000 of this cost is expected to come from international sources, including through technical assistance and capacity building.

4. Accelerating Deployment of Small-Scale Hydro in Uzbekistan

150. Over the last year, as part of a larger strategy to increase the use of renewable energy, the government of Uzbekistan has started looking into how to promote investment in hydropower, including small hydro—plants with installed capacity of less than 30 MW. On 5 May 2015, the President of Uzbekistan, 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.” In the very first paragraph, the resolution points out the importance of renewable energy. In the second paragraph, it sets forth a Road Map of 33 activities that must be undertaken in order to achieve the stated goals. Item #20 requests the Ministry of Economy, Ministry of Finance, Ministry of Agriculture and Water Resources, Uzbekenergo and the design institute “Hydroproject” to develop the State Program for Development of Hydro Power for 2016-2020. The program must be approved by the end of the third quarter of 2015. Existing drafts of the program, written earlier by Uzbekenergo, foresee construction of 76 new hydropower plants (HPPs) with a total generating capacity of 2,512 MW and rehabilitation of 33 existing HPPs that would increase their capacity to 1,973 MW.

151. Recently, a new Program for Development of Small Hydro 2015–2030 was developed by the Ministry of Agriculture and Water Resources and is currently going through the appraisal process within the government. This new program provides for the construction of 19 small HPPs with a total capacity of 210 MW and requires investment of $727.2 million. With passing of the Resolution 2343 and approval of the Road Map, this program will become a part of the wider program of hydropower development for 2016–2020[34] and is likely to be adjusted in scope and timing given the other developments related to hydropower. Most likely, the program will be combined with development plans for the small hydropower plants (SHPs) under the jurisdiction of Uzbekenergo, or it may be absorbed into a general program covering all HPPs.

152. The goal of this NAMA is to support the government’s efforts to accelerate the construction and rehabilitation of more SHPs through increased investment, capacity building, clarification of institutional roles, and improvement of legal and regulatory norms. The NAMA will supplement government plans with an analysis and comprehensive identification of the gaps still preventing implementation. This includes improving the technical skills for evaluating, planning and constructing SHPs and implementation of measures to accelerate the utilization of both public and private capital for financing planned hydropower capacity.

153. The NAMA will be implemented from 2015 to 2030 in accordance with the Program of Small Hydropower Development, which is expected to be approved by the end of 2015. The activities proposed for the NAMA include the following:

[34] See Review.uz, online version of the monthly “Economic Review.” *Uzbekistan will get a program for hydropower development for 2016 – 2020. May 6, 2015.* http://www.review.uz/index.php/novosti-main/item/2505-v-uzbekistane-poyavitsya-programma-razvitiya-gidroenergetiki-na-2016-2020-gody

(i) Analysis of institutional issues and elaboration of suggestions to optimize the institutional structures related to the development of small hydropower;
(ii) A comprehensive study of legal issues, primarily the problems of ownership of hydropower generating assets or other impediments to private investment, and development of solutions;
(iii) Clarification of the dispatch of hydropower and development of the means to provide potential investors with assurance that their electricity will be purchased as long as it is economically viable;
(iv) Analysis and development of a proposal introducing a special tariff for small hydropower production;
(v) Consideration of incentives for importing small hydro equipment and specific steps to promote its domestic production, if viable;
(vi) Developing proposals for attracting foreign and domestic private investment to the sector;
(vii) Education, training and capacity building in the field of small hydropower, including curriculum development, student exchange and study abroad programs, and targeted workshops and conferences;
(viii) Development of an updated atlas of small hydro potential in Uzbekistan; and
(ix) Investment in the construction and modernization of SHPs.

The NAMA is expected to result in GHG emission reductions of about 918,715 tCO_2e per year by 2030.

154. The implementation cost is $728.65 million, and includes construction of 19 SHPs and rehabilitation of three existing HPPs. $82.47 million for capacity building, technical assistance, and construction of new SHPs is expected to be covered through international assistance.

155. The proposed implementing agencies for the NAMA are the Ministry of Agriculture and Water Resources and Uzbekenergo.

E. Formulation of Climate Change Investment Concepts (Output 2)

156. Output 2 of the TA involves the identification and formulation of three climate change investment concepts. Together with the ADB and stakeholders, it was determined that these concepts should be based on individual components of the proposed NAMAs noting that early investment into specific parts of the NAMA may help increase the success of the overall policy framework set forth in the NAMA.

157. The identification of the individual investment concepts could not begin until the national stakeholders had made a decision regarding which NAMA concept(s) to focus on for the TA. Once the NAMAs were conceptualized, the consultants began working with the NAMA proponents to identify and formulate the specific investment projects.

158. The three proposed investment concepts, which are attached in Appendix 2 to this Final Report, include the following:

(i) Construction of solar photovoltaic (PV) and biogas plants at the Samukh Agro-Energy Residential Complex in Azerbaijan;
(ii) Construction of a network of 10 CNG refueling stations in Kazakhstan; and
(iii) Construction of the Tuyabuguzskaya SHP in Uzbekistan.

159. The concept notes, which are summarized in Table 36, focus mostly on investment in hard components, such as specific renewable energy projects in Azerbaijan and Uzbekistan and CNG refueling infrastructure in Kazakhstan. In the case of Kazakhstan, the investment concept also includes soft components based on institutional support elements. 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 36: 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)	15.9	25.4	19.8
International Funding Share	9.6 – 12.7	11.8 - 15.9	16.8
IRR (%)	10.96 – 14,73	13 - 30	11.86
NPV ($)	550,300 – 1,550,000	594,656 - 3,307,706	675,000
Simple Payback Period (Years)	15.5	3.2 to 9	12.5
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

Source: TA 8119 project documents.

160. The climate change investment concept notes are written as stand-alone documents that can be circulated among potential funding agencies. They address the following elements:

(i) Background on the potential mitigation option, i.e., renewable energy in Azerbaijan, natural gas for transport in Kazakhstan, and small hydro power in Uzbekistan;
(ii) A description of the relevant policy, institutional, and regulatory framework affecting the mitigation option;
(iii) The NAMA concept which the investment opportunity is part of;
(iv) Summary of the individual investment opportunity;
(v) Technical parameters;
(vi) Financial parameters;

(vii) Sensitivity analysis and risk management;
(viii) Implementation arrangements; and
(ix) Other items, as applicable.

IV. RESULTS ACCORDING TO THE DESIGN AND MONITORING FRAMEWORK OF RETA 8119

161. Table 37 presents progress in meeting the performance targets under the Design and Monitoring Framework (DMF) for RETA 8119 (the TA). At the time of writing this Final Report, the report on the Economics of Climate Change and the report on the four NAMAs are being finalized incorporating stakeholder comments received during the July 2015 final workshops. Concept notes for the three climate change mitigation investment proposals are attached along with this Final Report.

162. The DMF includes a target of training 60 officials in GHG measuring and monitoring, with 30% of them women. To date 254 national decision makers have been trained during two regional and four national workshops. Of these, women represent 89 (or 35%) of the experts trained.

163. As noted in Table 37 several of the study countries have already started using the initial results from the TA in their national reports to the UNFCCC. Specifically, Azerbaijan's first Biennial Update Report (BUR) submitted to the UNFCCC in March 2015 references the initial results of the economic analysis performed under TA 8119.[35]

[35] Government of Azerbaijan. 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

Table 37: Results According to the Design and Monitoring Framework of RETA 8119

Design Summary	Performance Targets and Indicators with Baselines	Data Sources and Reporting Mechanisms	Results
Outcome: The cost of climate change in the target countries is better understood	Cost of climate change mitigation reported in at least one national communication to the UNFCCC by 2015	National communication to the UNFCCC	Azerbaijan's draft Third National Communication to the UNFCCC references the findings from the economic analysis performed under TA 8119. The government of Azerbaijan will submit the Third National Communication to the UNFCCC later in 2015.
Output 1: The cost of climate change mitigation is estimated in Azerbaijan, Kazakhstan and Uzbekistan	National reports on the economics of climate change mitigation endorsed by Azerbaijan, Kazakhstan, and Uzbekistan by 2014	National reports on economics of climate change mitigation	Country endorsement of the report on the economics of climate change mitigation is pending. Azerbaijan's first Biennial Update Report (BUR) submitted to the UNFCCC in March 2015 references the initial results of the economic analysis performed under TA 8119. [a] Submission of a BUR is a new reporting requirement under the UNFCCC to enhance reporting in national communications, including inventories, from non-Annex I Parties on mitigation actions and their effects, needs and support received. Inclusion of the results from the TA in a BUR thus indicates government endorsement. In addition, Uzhydromet in Uzbekistan has expressed an interest in using the national model constructed in LEAP to prepare the country's Third National Communication to the UNFCCC.
Output 2: Climate change mitigation investment opportunities identified in Azerbaijan, Kazakhstan and Uzbekistan	Appropriate national mitigation actions formulated for Azerbaijan, Kazakhstan and Uzbekistan by 2014	National mitigation strategy documents	During the final workshops in July 2015, national counterparts indicated they intend to submit the NAMA concepts developed under this TA to the UNFCCC NAMA Registry. National stakeholders have started implementing various NAMA sub-components and are reaching out to donors for support. The NAMA to develop a National Energy Efficiency Support System for Kazakhstan has received part of the requested funding from the World Bank.
	60 officials trained on GHG measuring and monitoring, of which 18 (30%) are women (2011 baseline: 0%)	Workshop reports	254 national decision makers have been trained. Women represent 89 (or 35%) of these.
	Three climate change mitigation investment proposals formulated by 2014	Concept notes	Investment concept notes for Azerbaijan, Kazakhstan, and Uzbekistan are submitted along with this Final Report.

[a] Government of Azerbaijan. 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

Source: TA 8119 project documents.

V. LESSONS LEARNED AND RECOMMENDATIONS FOR NEXT STEPS

164. This report synthesizes the results of RETA 8119, Economics of Climate Change Mitigation in Central and West Asia. The TA produced national economic assessments of mitigation opportunities in the energy and transport sectors of Azerbaijan, Kazakhstan, and Uzbekistan and developed the capacity of decision makers on the economic analysis of mitigation and measurement of GHG emissions. The TA also resulted in the formulation of four NAMAs and three climate change mitigation investment opportunities across the renewable energy, energy efficiency, and transport sectors.

165. Economic analysis undertaken in the TA indicates that anticipated growing populations and improving economies in Azerbaijan, Kazakhstan, and Uzbekistan promise to put further pressure on energy resources, including greater demand for motorized transport and electricity. If the energy and transport systems of Azerbaijan, Kazakhstan, and Uzbekistan remain as carbon-intensive as today, significant increases in GHG emissions will follow. The emissions associated with this growth in economic activity and energy requirements will likely offset expected improvements in energy and GHG intensity, particularly in Kazakhstan and Uzbekistan. This in turn will lead to a continued rise in GHG emissions through 2050.

166. This situation presents an opportunity to re-examine resources and energy options and pursue green-growth strategies that enable increased development with lower climate impacts. The utilization of cost-effective clean energy technologies and the promotion of energy efficiency, fuel switching, and low-carbon transport can play a crucial role in achieving these goals. Understanding the potential of such approaches will also support the region in leveraging public and private sector finance for prioritized mitigation options that contribute to national development goals.

167. The TA economic analysis indicates that a number of cost-effective, nationally appropriate mitigation options are available to Azerbaijan, Kazakhstan, and Uzbekistan to help them decarbonize their economies at no or very low cost. In Azerbaijan, implementation of all low- and moderate-cost technical measures analyzed (i.e., < 50 2007 AZN per tCO_2e) will result in a cumulative reduction of GHG emissions of 12% by 2050 compared to the *no action* scenario. This can be done at an overall negative cost to society of \$ -1.3 per tCO_2e. In Uzbekistan, implementation of all the technical mitigation measures analyzed can result in an 8% reduction in emissions by 2050 at a social cost of \$ -17.2 per tCO_2e. This means overall savings to GDP for both countries. In Kazakhstan, implementation of all the low-cost measures analyzed can result in a 13% reduction in emissions by 2050 at a social cost of \$ 5.2 per tCO_2e.

168. Particularly attractive measures include SOCAR's Eco-driving program, commercial and residential CFL lighting, and small hydro in Azerbaijan; the introduction of CNG vehicles, improved heat pump insulation, coalbed methane capture, and efficient new homes in Kazakhstan; and residential efficiency and renewable energy and small and large hydro in Uzbekistan. In addition, several low-cost measures in all three countries involve introduction of increased renewables such as solar, wind, and biomass. The proposed NAMAs to promote small hydro in Uzbekistan, CNG and energy efficiency in Kazakhstan, and renewable energy in Azerbaijan are intended to take advantage of these low costs and accelerate mitigation by removing some of the barriers to implementation.

169. In Azerbaijan, the removal of price subsidies in the energy sector represents a low-cost measure with a potential for very large emission reductions. In Kazakhstan, the natural gas power target, the alternative power target, a CO_2 cap on power generation, a price on carbon

such as through emissions trading, 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 low to no cost, the government of Kazakhstan is moving ahead with the Green Growth Concept, which establishes an overall framework for accelerated mitigation. Azerbaijan and Uzbekistan will need to re-examine existing barriers to the deployment of clean energy and transport options, such as unfavorable tariffs for renewable energy, in order to ensure that the menu of mitigation options analyzed in this report can be fully implemented. As indicated in the investment concepts attached along with this Final Report, investment projects based on solar and biomass in Azerbaijan and small hydro in Uzbekistan are not economically viable under current tariff structures, even though modeling under the TA indicates these renewables are economically attractive from a social cost perspective.

170. When combined into mini-scenarios, the technical mitigation options included in this study have an appreciable effect on projected GHG emissions in the medium term (i.e., through 2030). However, they will not able to prevent the significant increase in GHG emissions in the long run. 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 and other low-carbon fuels for buildings and transport 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.

171. Significantly slowing the increase in long-run emissions (i.e., 2030-2050) will require introduction of additional measures targeting energy use for buildings, industry, and transport and pushing efficiency further than that modeled in the TA. It also requires switching to low-carbon sources such as electricity, biofuels, and hydrogen; introduction of a meaningful carbon price; and integrated land use planning in urban areas to reduce vehicle and passenger miles. Additional de-carbonization of the power sector is also likely necessary. Such pathways will be more costly and very ambitious, however, and may only be feasible if supporting international finance and technical cooperation is available.

172. Building up and strengthening the institutions and expertise for accessing climate finance is therefore crucial for Azerbaijan, Kazakhstan, and Uzbekistan. Increasingly, the climate finance community is emphasizing the importance of measuring, monitoring, and verifying that the resources provided are producing measurable and transformative GHG emission reductions. As a result, the three countries will need to establish clear frameworks and procedures for tracking climate finance and developing indicators for measuring and monitoring impacts on GHG emissions and associated co-benefits metrics. Azerbaijan has started this process by drafting language in support of NAMA implementation in the new Action Plan on the Improvement of the Environmental Situation in Azerbaijan for 2014–2020 and the new State Programme on Energy Efficiency for the period of 2015–2020, which are expected to be adopted by the end of 2015. Strategies for climate change mitigation, alternative and renewable energy development, and NAMAs have been reflected in the draft text of these documents.

173. Second, in support of the UNFCCC negotiations towards a new climate change agreement, there is a growing focus on preparing quantified assessments of future GHG emission trajectories and potential emission reduction pathways, as witnessed by the international guidance on preparing INDCs ahead of the Conference of Parties (COP 21) to the UNFCCC in Paris in December 2015. The governments of Azerbaijan, Kazakhstan, and Uzbekistan must continue to build on national GHG modeling efforts such as the one conducted under this TA, and extend these to sector-based analyses as well. Kazakhstan has already

developed the national expertise to conduct similar modeling through academic institutions including Nazarbayev University. To assist countries continue work in this area, ADB will distribute the national models and the supporting documentation to the counterpart governments at the completion of this TA and the models will be made available publically at ADB and SEI's websites.

174. Third, given the need to work across traditional sectors and line ministries to implement truly transformative mitigation actions and NAMAs that reach across several sectors and/or incorporate innovative financing mechanisms, there is a need for inter-agency committees or other institutions for coordinating such efforts. As discussed further in the *Report on Nationally Appropriate Mitigation Actions (NAMAs) in Azerbaijan, Kazakhstan, and Uzbekistan* some of the NAMA concepts developed under this TA, such as the National Energy Efficiency Support System for Kazakhstan, can benefit from collaboration across multiple line agencies to broaden the reach of the NAMA. Such collaboration would be made easier if supported by an institution or body with the mandate to incentivize and coordinate inter-agency efforts. The introduction of such a body could be modeled after the countries' existing arrangements for the Clean Development Mechanism (CDM), as these have proved effective at promoting collaboration across many agencies.

175. Finally, 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. One example is Bank Respublika in Azerbaijan, which is partnering with the IFC to provide eco-loans for energy-efficient equipment, building retrofits, and repair of existing energy appliances. The Bank also manages a program to retrofit appliances that are switched to using renewable energy.

176. Azerbaijan, Kazakhstan, and Uzbekistan will also need to establish capable national bodies which can facilitate climate finance projects and coordinate the work of implementing entities. This includes establishing Nationally Designated Authorities in order to obtain funds from the Green Climate Fund, such as those already announced by the governments of Kazakhstan and Uzbekistan. It will also be necessary to develop capacity within relevant ministries to prepare, process, and appropriately screen projects for climate change mitigation opportunities. Paired with a solid understanding of opportunities to cost-effectively reduce emissions, such institutions will be well situated to leverage the full range of available resources for the implementation of mitigation options that contribute to national development goals.

APPENDIX 1: TECHNICAL ASSISTANCE DESIGN AND MONITORING FRAMEWORK

Table A.1: Design and Monitoring Framework

Design Summary	Performance Targets and Indicators with Baselines	Data Sources and Reporting Mechanisms	Assumptions and Risks
Impact Climate change actions are implemented in the target countries.	CO_2 equivalent per capita reduced by 5% by 2020 (2010 baseline: 5.2 tCO_2e/capita in Azerbaijan, 14.5 tCO_2/capita in Kazakhstan and 4.42 tCO_2e/capita in Uzbekistan)	National GHG inventories	Assumption Policy and decision makers consider climate change a priority issue.
Outcome The cost of climate change in the target countries is better understood.	Cost of climate change mitigation reported in at least one national communication to the UNFCCC by 2015	National communication to the UNFCCC	Assumption Governments are supportive of climate change programs.
Outputs 1. The cost of climate change mitigation is estimated in Azerbaijan, Kazakhstan, and Uzbekistan. 2. Climate change mitigation investment opportunities are identified in Azerbaijan, Kazakhstan, and Uzbekistan.	National reports on the economics of climate change mitigation endorsed by Azerbaijan, Kazakhstan, and Uzbekistan by 2014 Appropriate national mitigation actions formulated for Azerbaijan, Kazakhstan, and Uzbekistan by 2014 60 officials trained on GHG measuring and monitoring, of which 18 (30%) are women (2011 baseline: 0%) Three climate change mitigation investment proposals formulated by 2014	National reports on economics of climate change mitigation National mitigation strategy documents Workshop reports Concept notes	Assumptions Governments and national stakeholders provide relevant data and information. Governments support the introduction of new incentives. Stakeholders participate in consultations and national expert workshops.

Source: Request for Proposal: RDTA 8119: Economics of Climate Change in Central and West Asia.

Table A.2: Activities and Milestones

1.	**Output 1: The cost of climate change mitigation is estimated in Azerbaijan, Kazakhstan, and Uzbekistan**
1.1	Review National Mitigation Policies and Measures (Year 1)
1.2	Develop Stakeholder Engagement and Communication Plan (Year 1)
1.3	Conduct Three National and One Regional Inception Workshops (Year 1)
1.4	Define Methodology for Mitigation Analysis
1.5	Establish GHG Emission Baselines (Year 1)
1.6	Project GHG Emissions up to 2050 (Year 1)
1.7	Develop GHG marginal abatement cost curves (Year 1)
1.8	Estimate Cost and Benefits of Mitigation Options (Year 1)
1.9	Conduct Three National and One Regional Interim Workshops (Year 2)
1.10	Identify Priority Mitigation Measures for Energy and Transport in Azerbaijan, Kazakhstan, and Uzbekistan (Year 1)
1.11	Produce Knowledge Products on the Study's Objectives, Methodologies, and Findings (Years 1 and 2)
1.12	Produce Country Reports on the Economics of Climate Change Mitigation for Azerbaijan, Kazakhstan, and Uzbekistan (Year 1)
2.	**Output 2: Climate change mitigation investment opportunities are identified in Azerbaijan, Kazakhstan, and Uzbekistan**
2.1	Conduct Consultations with Stakeholders from Energy, Transport, and Finance Sectors and Capital Markets (Year 2)
2.2	Identify Market Barriers and Opportunities for Mitigation Investments (Year 2)
2.3	Support Formulation of Nationally Appropriate Mitigation Actions in Azerbaijan, Kazakhstan, and Uzbekistan (Year 2)
2.4	Formulate Investment Proposals (Year 2)
2.5	Conduct Three Final National and One Final Regional Workshops (Year 2)
2.6	Disseminate Knowledge Products on the Study's Findings at the 20th Conference of the Parties to the UNFCCC and other International Conferences (Year 2)

APPENDIX 2: CLIMATE CHANGE INVESTMENT CONCEPTS IN AZERBAIJAN, KAZAKHSTAN, AND UZBEKISTAN

RETA 8119 Economics of Climate Change in Central and West Asia: Mitigation Component

Investment Concept Note

Construction of Solar PV and Biogas Plants
at the Samukh Agro-Energy Residential Complex

Within the NAMA

Promoting Agro-Energy Development
Based on Renewable Energy in Azerbaijan

ABBREVIATIONS AND ACRONYMS

ADB	Asian Development Bank
CO_2	Carbon Dioxide
GDP	Gross Domestic Product
GHG	Greenhouse Gas
IPCC	Intergovernmental Panel on Climate Change
IRR	Internal Rate of Return
MRV	Monitoring, Reporting, and Verification
NAMA	Nationally Appropriate Mitigation Actions
NPV	Net Present Value
OECD	Organization for Economic Cooperation and Development
OFAT	One-Factor-at-a-Time
SAARES	Alternative and Renewable Energy Agency
tCO_2e	Tonnes of Carbon Dioxide Equivalent
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
$	US Dollar

CURRENCY EQUIVALENTS

(as of 6/15/2015)

1 AZN = 1.04883 $
1 AZN 2007 = 1.2703 $ 2015

INVESTMENT OPPORTUNITY IN AZERBAIJAN

A. The Investment Opportunity

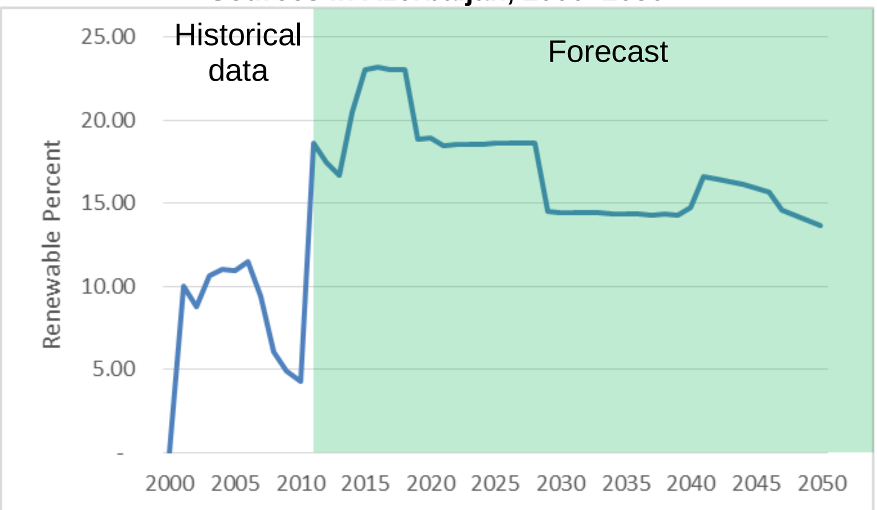
177. The investment opportunity described in this concept note is part of the NAMA proposed by the Azerbaijan State Agency on Alternative and Renewable Energy Sources (SAARES) to accelerate renewable energy development in the agriculture sector. The opportunity falls under the jurisdiction of SAARES 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 Agro-Energy Residential Complex, including:

(i) A solar photovoltaic (PV) power plant with a capacity of 3.2 MW; and
(ii) A biogas plant with capacity for 0.75 MW of electricity and 0.75 MW of heat generation.

B. Background

178. In 2010, 98.8% of Azerbaijan's primary energy supply was met by fossil fuels. Since then, several new renewable energy facilities have come online (Figure 1), but even so, 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 1).

Figure 1: Percentage of Electricity Generation from Existing and Planned Renewable Sources in Azerbaijan, 2000–2050



Source: ADB. Forthcoming. *Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs,* Manila.

Table 1: Potential Renewable Resource Yields

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

Source: Ministry of Ecology and Natural Resources of Azerbaijan Republic (2012)

C. Policy, Institutional, and Regulatory Framework for Renewable Energy

179. 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 Programme 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 SAARES. In 2011, the President issued a new order setting a target for alternative and renewable energy for 2020, 9.7% of total energy and 20% of electricity consumption, as well as a target of 2,000 MW of renewable energy capacity installed.[1] SAARES was directed to develop a strategy to meet this target.

180. 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 between 2015-2018. Altogether, the plan will result in 735 MW new alternative and renewable energy.[2] 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 end of 2015.

D. NAMA to Promote Agro-Energy Development Based on Renewable Energy

181. 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 Nationally Appropriate Mitigation Action (NAMA) that accelerates the adoption of renewable energy in the agricultural sector. The NAMA is designed to address barriers to renewables by helping the government reform the legal and regulatory norms governing renewable energy. The NAMA is described in more detail in the TA report on NAMAs in Azerbaijan, Kazakhstan, and Uzbekistan.[3]

182. The NAMA will also support the construction and implementation of the Samukh Agro-Energy Residential Complex—a modern renewable energy–powered multifaceted agriculture and food processing center, and as close to a carbon-neutral and waste-free operating cycle as possible. The Samukh Complex will include several lines of agricultural production and up to 1,000 residential units to house workers and refugees from the Nagorno-Karabakh region. The Complex will be powered by a variety of renewable sources for electricity and heat, including solar, geothermal, and locally produced biomass (waste generated from the Samukh Complex's operations or collected from the nearby region). Whereas there are a small, if growing, number of agricultural complexes in Azerbaijan, this would be the first such complex to be powered by renewable energy. SAARES will use the lessons learnt and the technical skills gained from the

[1] 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.

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

[3] ADB. *Report on Nationally Appropriate Mitigation Actions (NAMAs) in Azerbaijan, Kazakhstan, and Uzbekistan.* Manila. August 2015.

Samukh Complex to replicate it at five other locations in Azerbaijan and encourage other agricultural enterprises to adopt renewable energy at their production facilities.

E. Background on the Investment Opportunity

183. The investment opportunity involves financing of the construction and commissioning of two of the power plants that will be built during Phase 1 of the Samukh Agro-Energy Residential Complex, including:

(iii) A solar photovoltaic (PV) power plant with a capacity of 3.2 MW; and
(iv) A biogas plant with capacity for 0.75 MW of electricity and 0.75 MW of heat generation.

184. The investment in these facilities will result in increased technical experience with solar PV and biomass in the agriculture and rural residential sectors. SAARES will use this experience for replication elsewhere at Samukh and at other agricultural sites in Azerbaijan, the number of which is growing along with privatization of the agricultural sector and increasing agricultural production.[4] 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.

185. The first phase of the NAMA establishing the Samukh pilot is already underway and continues through 2016. Phase 1 started in 2014 and, so far, has focused on feasibility studies to determine the specific renewable energy technologies to be deployed and their cost. This investment proposal is part of Phase 1, which also includes work to improve the normative and legal framework for renewable energy, as well as a feasibility study to optimize the design of the Complex's agricultural and food processing facilities that should further clarify the expected energy demand.

F. Technical Parameters

186. 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 km^2 with a population of 56,300 as of 2014.

187. 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 W and cost about 500 AZN ($ 524). These panels are manufactured in Azerbaijan by the factory Azguntex, which is located north of the capital Baku.

188. 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.

[4] FAO 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. Accessed at: http://www.fao.org/docrep/field/009/aq671e/aq671e.pdf

G. Financial Parameters

189. 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). This is estimated to result in X kWh electricity generation and X MJ heat.

190. 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 under Output 1 of the TA (Table 2). This includes an assumed capacity cost for solar PV of 3,000 AZN/KW ($ 3,147). Using the assumptions in Table 2, 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.

Table 2: Assumptions Used in Financial Analysis of the Solar PV 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 Linear approximation for 2015	RETA 8119 Output 1 Economic model for Azerbaijan. 3,334.69 in 2010, dropping to 884.71 in 2040 The range compares with estimations from other international literature and Asguntex cost of a unit panel (500 AZN 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

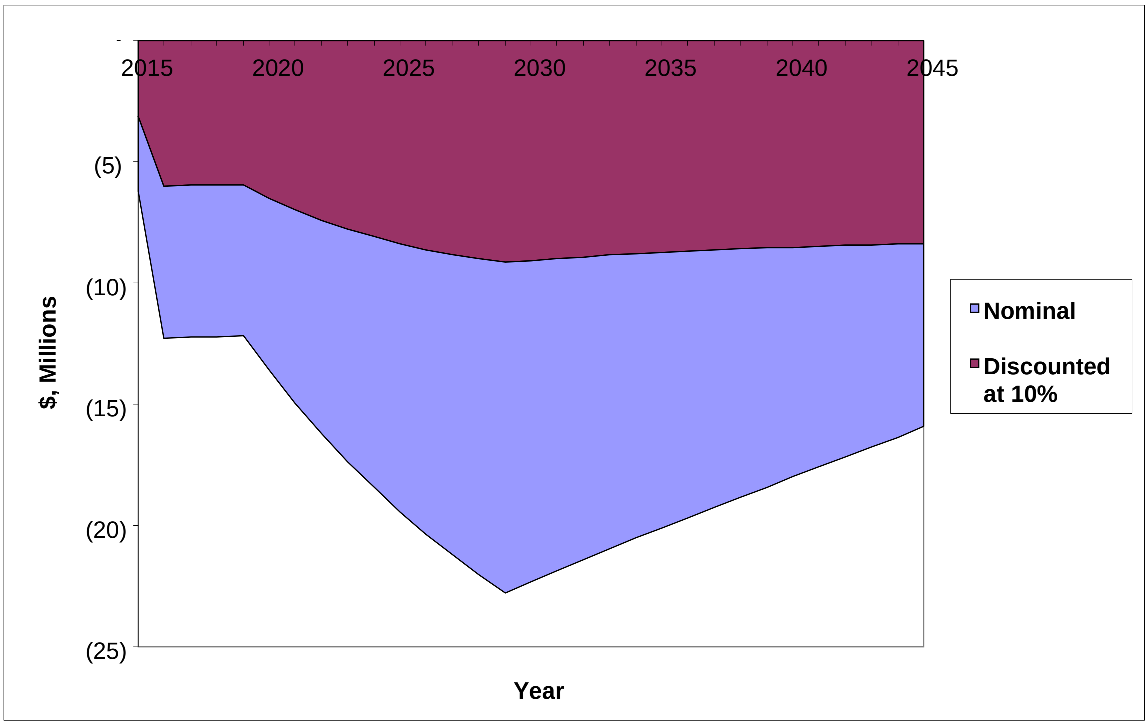
Source: ADB. Forthcoming. Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs. Manila.

191. 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.

192. 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 (from the ADB Libor-based loan description[5]), and additional fees from 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%.

193. At the current tariff the project is not economically 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 2). 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.

Figure 2: Cumulative Cash Flow of the Samukh Solar PV and Biogas Plants Current Tariff of 0.06 AZN/kWh



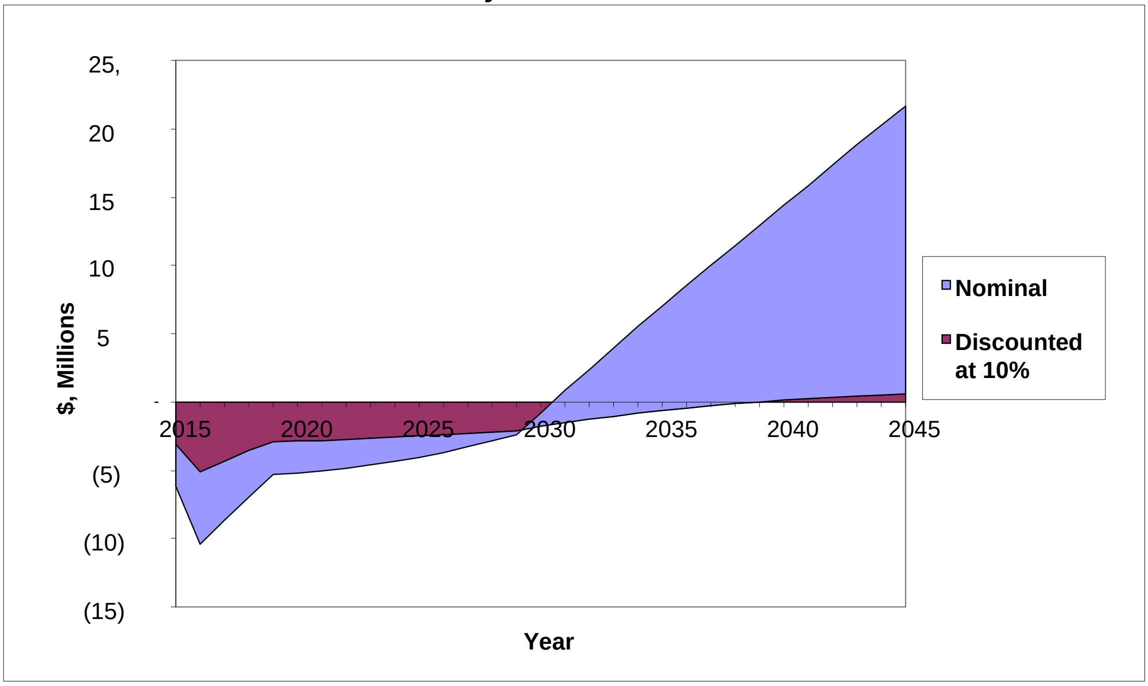
Source: Abt Associates analysis.

194. As noted above, SAARES is looking to revise the tariffs for renewable energy by the end of 2015. It is in the process of negotiating an electricity purchase agreement with the national utility, AzerEnerji. Moreover, the ongoing feasibility study at the Samukh Complex may result in the identification of other ways to reduce costs. As a result, the economics of this investment opportunity could improve.

[5] ADB. *Overview of LIBOR-based Loans: Sovereign and Sovereign-Guaranteed Borrowers.* Institutional Document. January 2014. http://www.adb.org/documents/overview-libor-based-loans-sovereign-and-sovereign-guaranteed-borrowers

195. If the government increases tariffs from 0.06 AZN/kWh to 0.18 AZN/kWh,[6] the project IRR rises to 10.96%, the NPV at a discount rate of 10% turns into $ 550,300 and the simple payback period becomes 15.5 years. This is the minimum tariff under which a discounted payback period of about 24 years falls within the lifetime of the project (see Figure 3).

Figure 3: Cumulative Cash Flow of the Samukh Solar PV and Biogas Plants Electricity Tariff at 0.18 AZN/kWh



Source: Abt Associates analysis.

196. 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.

H. Implementation Arrangements

197. 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.

198. 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 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.

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

I. Sensitivity Analysis and Risk Management

199. A simplified sensitivity assessment using the One-factor-at-a-time (OFAT) method identifies the following risks (see Table 3) 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 3 while the ones with the least risk are listed at the bottom.

Table 3: Sensitivity Analysis of the Samukh Solar PV 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	+-158
Loan-to-project cost ratio	+0.767 or -0.548	+- 302,665	+-6	+-55
Profit tax	+-0.438	+- 264,144	+-4	+-48
Heat tariff	+0.219 or -0.11	+- 93,551	+-2	+-17
Interest rate	+- 0.11	+- 49,527	+-1	+-9
Level of commercial losses	0	+- 16,509	+-0	+-3

Source: Abt Associates analysis.

200. 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 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.

201. 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 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 and NPV of 14% and 158% respectively. 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.

202. 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.

203. 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.

J. Other

204. 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.

205. 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 kWh electricity and MJ 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.* Manila. August 2015.

RETA 8119 Economics of Climate Change in Central and West Asia: Mitigation Component

Investment Concept Note
Construction of a Network of 10 CNG Refueling Stations

Within the NAMA
Fostering Use of Natural Gas in the Transport Sector of Kazakhstan

ABBREVIATIONS AND ACRONYMS

CNG	Compressed Natural Gas
CNG-FS	CNG Fueling Station
CO_2	Carbon dioxide
GDP	Gross Domestic Product
ICN	Investment Concept Note
IPCC	Intergovernmental Panel on Climate Change
IRR	Internal Rate of Return
JSC	Joint Stock Company
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
NAMA	Nationally Appropriate Mitigation Action
NGV	Natural Gas Vehicle
NPV	Net Present Value
tCO_2e	Tonnes of Carbon Dioxide Equivalent
TPES	Total Energy Supply
UNDP	United Nations Development Programme
UNFCCC	United Nations Framework Convention on Climate Change
$	US Dollar

CURRENCY EQUIVALENTS
as of 06/15/2015

1 KZT = 1/186.25 = 0.00537 $

INVESTMENT OPPORTUNITY IN KAZAKHSTAN

A. The Investment Concept

206. The investment opportunity described in this concept note is part of the NAMA proposed by the natural gas Joint Stock Company (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 compressed natural gas (CNG) refueling stations (CNG-FS). 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.

B. Background

207. Kazakhstan relies mainly on gasoline and diesel for transport. The share of natural gas in total fuel consumed is below one percent.[1] 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 m^3.[2]

208. As presented in Table 1 below, CNG is much cheaper than gasoline and diesel. The price of natural gas and 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.

Table 1: Prices for Transport Fuels in Kazakhstan, 2000-2050 (2010 $ / GJ)

Fuel	Historical			Forecast							
	2000	2005	2010	2015	2020	2025	2030	2035	2040	2045	2050
CNG	0.6	1.2	1.2	1.8	2.1	2.4	2.8	3.3	3.8	4.4	5.1
Diesel	8.3	5.3	9.9	15.1	17.5	20.3	23.6	27.3	31.7	36.7	42.6
Gasoline	10.1	6.5	9.9	14.0	16.3	18.9	21.9	25.4	29.4	34.1	39.5
LPG	3.9	6.0	6.2	9.1	10.6	12.2	14.2	16.4	19.1	22.1	25.6
Natural Gas	0.4	0.8	0.8	1.2	1.4	1.6	1.8	2.1	2.5	2.9	3.3
Crude Oil	2.1	3.6	7.1	9.3	10.8	12.5	14.5	16.8	19.5	22.6	26.2

CNG = compressed natural gas, LPG = liquefied petroleum gas
Source: ADB. Forthcoming. Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs. Manila.

[1] ADB. Forthcoming. Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs. Manila.
[2] Ministry of Industry and New Technologies of Kazakhstan, 2014. *Draft Concept on Fuel and Energy Development to 2030 for Kazakhstan*; and 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.

C. Policy, Institutional, and Regulatory Framework for Natural Gas for Transport

209. Among the priority measures of the government's 2013 *Concept of Transition of the Republic of Kazakhstan to a Green Economy*[3] and the territorial development programs for the transport sector, is the transition to natural gas in vehicles in cities. The goal is to minimize the impact of urban/regional transport on the environment and public health and reduce dependence on more expensive and often imported fuels. The development of natural gas infrastructure is also emphasized in the "Governmental Program of Development and Integration of Transport Infrastructure of the Republic of Kazakhstan until 2020".[4]

210. Vehicle ownership is growing in Kazakhstan. About 3,766 thousand vehicles with gasoline and diesel engines are registered in the country.[5] More than 70% of these are classified as Euro-2 and below despite the fact that Euro-4 standards were introduced in Kazakhstan in January 2014. Euro-5 standards will be introduced in January 2016. As a result, there will be a big push to upgrade the existing vehicle fleet to more fuel efficient standards which will fit well with the strategy of switching to CNG in urban environments.

D. NAMA to Foster the Use of Natural Gas in the Transport Sector

211. In support of the country's goal to increase the use of natural gas and slow the growth of GHG emissions, ADB has partnered with stakeholders in Kazakhstan to develop a NAMA concept that will foster the use of natural gas in the transport sector. The NAMA will support the development of infrastructure for supplying CNG throughout the country and facilitate vehicle conversions in large fleets.

212. The current lack of refueling infrastructure is one of the most important barriers to the increased use of gas. The NAMA will also enable the 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 and protocols, and development of the necessary institutional and human capacity to support a switch to natural gas. The NAMA will be implemented by JSC KazTransGas and directly executed by its subsidiary LLP KAzTransGas Onimderi.

213. Implementation of the NAMA will enable the market for natural gas as an engine fuel, with the goal of increasing the share of natural gas vehicles to 15% (up to 50% in large cities). Implementation of the NAMA will help avoid GHG emissions from transport by encouraging a switch from diesel and gasoline to natural gas.

E. Background on the Investment Opportunity

214. In order to address the infrastructure problem, this investment concept note suggests supporting the natural gas company, JSC KazTransGas, in the construction of a network of 10 CNG-FS. The stations will serve as pilots in different cities and regions of Kazakhstan. They will become the basis for further market development and future construction of up to 100 CNG-FS

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[3] The 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

[4] Presidential Decree No. 725 dated 13 January 2014. www.mid.gov.kz/images/stories/contents/gp_150520141656.pdf

[5] Kazakhstanskaya Pravda, official national daily, May 20, 2015. *"Green" path to economy growth*. Interview with the Minister of Energy of Kazakhstan Mr. V.Shkolnik. http://www.kazpravda.kz/interviews/view/zelenim-kursom-k-rostu-proizvodstva/

and creation of other elements of the infrastructure for a natural gas refueling market in Kazakhstan. The investment concept includes institutional support elements such as 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 convert and maintain the vehicles.

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

(i) Construction of ten CNG-FS in different locations of Kazakhstan;
(ii) Completion of a feasibility study for the construction of additional 35 CNG-FS;
(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 liquefied natural gas (LNG) vehicles.

F. Technical Parameters

216. The investment concept involves the construction of 10 new CNG fueling stations (Figure 2) 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).

217. 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 that is being conducted and is due later this year.

G. Financial Parameters

218. The following section presents an economic analysis of the investment opportunity. Where specific data was lacking for the financial analysis, assumptions based on the experience gained from the ongoing construction of three CNG-FS in the cities of Kyzylorda, Shymkent, and Actobe, 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-FS to be funded as part of this investment concept.

Figure 2: Working Design of a CNG-FS with Refueling Capacity of 2100 m^3/hour

Notes: 1 – natural gas intake valves; 2 – technological box-unit, including compressor and CNG preparation equipment; 3 – CNG storage unit; 4 – fueling pump; and 5 – Automated Control System.
Source: JSC KazTransGas.

219. The cost and economic indicators for CNG refueling stations under construction are presented in Table 2. Despite the fueling stations being identical in design, the separate subprojects have internal rate of return ranging from 18% to almost 26%. This is due to the fact that 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.

220. 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 discussed in Section B, 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 an upcoming market analysis that JSC KazTransGaz intends to complete later in 2015.

Table 2: Economic and Technical Indicators for 3 CNG-FS Already Under Construction

Indicator	City		
	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$	0.259 – 0.56	0.259 – 0.419	0.288 - 0.420
Purchase price range for natural gas during project period (2015–2030), $/$m^3$	0.138 – 0.362	0.070 – 0.193	0.041 – 0.112
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

Source: Abt Associates analysis.

221. For the three CNG-FS, the total investment cost is $ 7,095,000 and the combined project Internal Rate of Return (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.

222. 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-FS 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.

223. The total funding required for the soft components is $6.5 million. These activities are 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.

224. With no investment into soft components, the total capital cost of the 10 CNG-FS 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 3), 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.

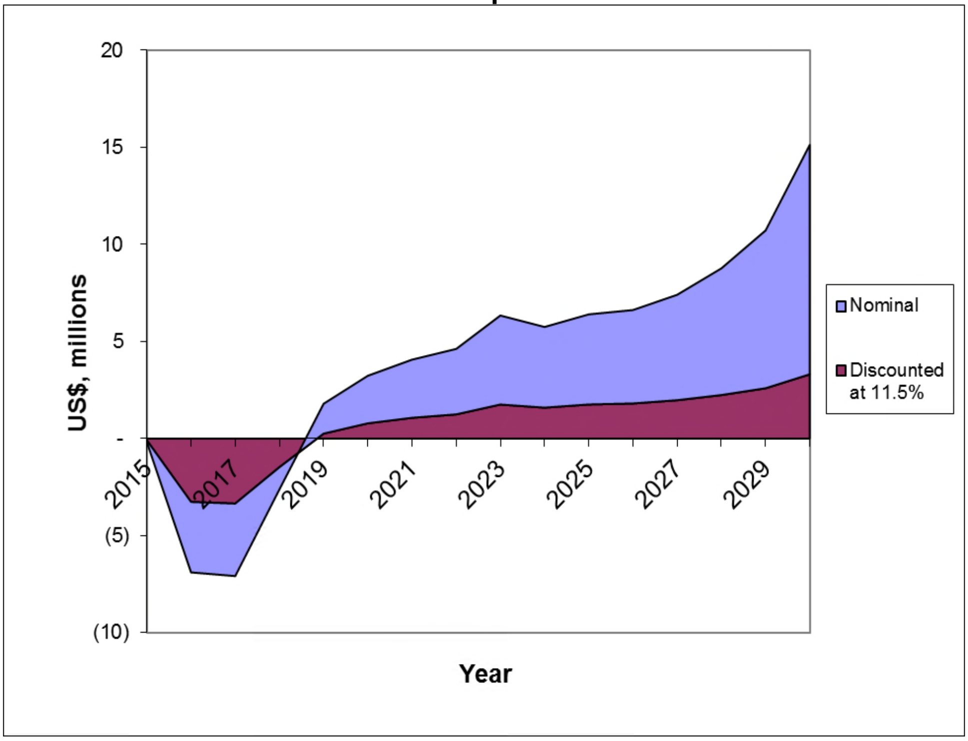
Table 3: Funding Request from KazTransGas for Phases 1 and 2 of the NAMA

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 CNG to medium and small commercial entities	**30,500,000**	250,000	7,930,000	**22,320,000**

Source: Abt Associates analysis.

225. Using the 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 a Net Present Value (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 four years. The cumulative cash flow in nominal and discounted dollars is shown in Figure 3.

Figure 3: Cumulative Cash Flow of the 10 CNG-FS with the Full Cost of Soft Components Rolled into the Loan



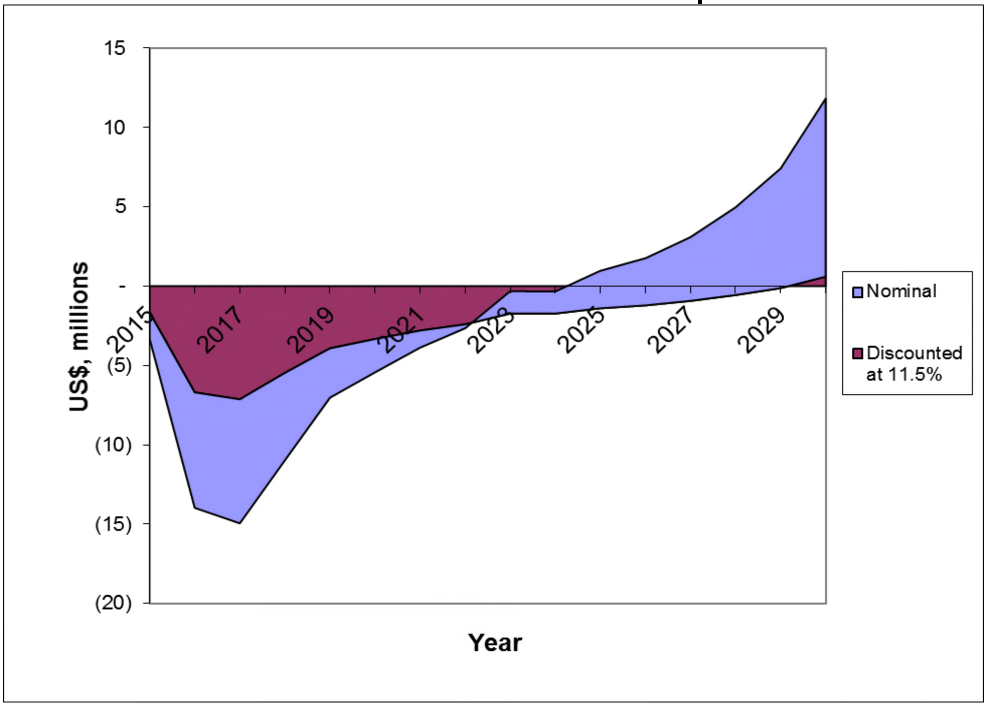
Source: Abt Associates analysis.

226. The irregular shape of the curves, with a decrease in accumulated cash in years 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 TransKazGas.

227. 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 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 4). Simple payback period becomes more than 9 years, while the discounted payback is over 14 years.

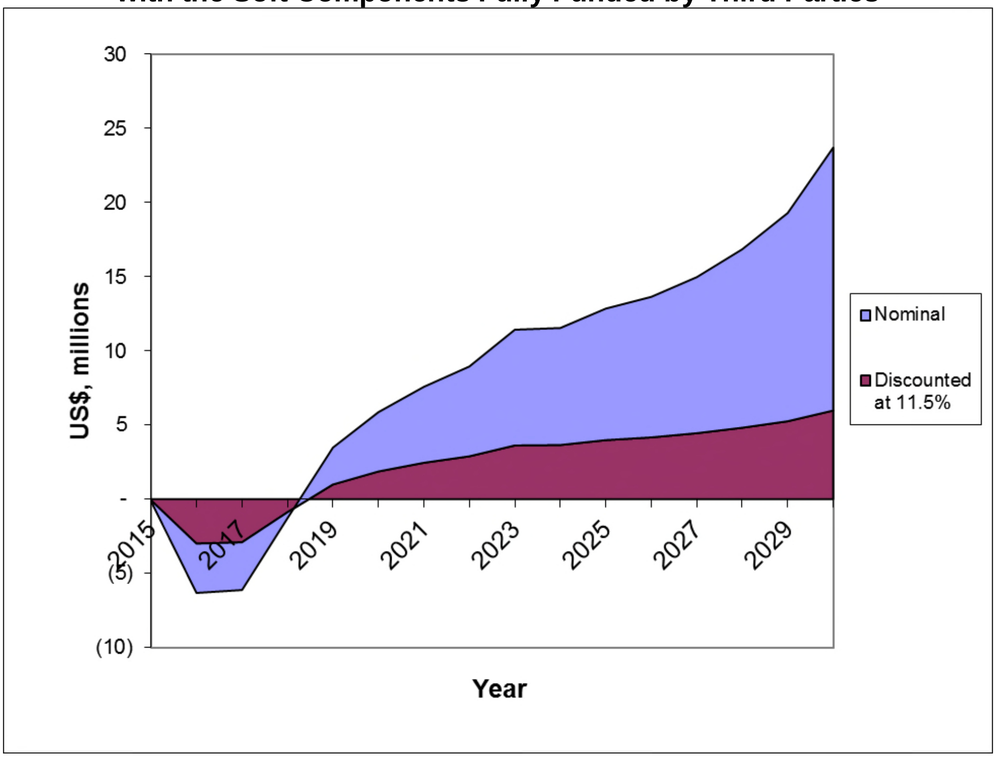
228. Alternatively, if the full cost of the soft components is absorbed by the third parties (grants, technical assistance), the economic indicators of the project improve drastically. In this case, the IRR is at 43.37%, NPV is at $ 5.98 million and both simple and discounted payback periods are just over three years (see the cash flow in
Figure 5).

Figure 4: Cumulative Cash Flow of the 10 CNG-FS with No Loan for the Cost of Soft Components



Source: Abt Associates analysis.

Figure 5: Cumulative Cash Flow of the 10 CNG-FS with the Soft Components Fully Funded by Third Parties



Source: Abt Associates analysis.

H. Sensitivity Analysis and Risk Management

229. Analysis of the data from the CNG-FS in Shymkent, Kyzyl-Orda, and Actobe 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 and the market base of CNG-FS grows.

230. 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.

I. Implementation Arrangements

231. 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.

232. KazTransGas Onimderi LLP, 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 LLP will work directly with JSC KazTransGas on matters related to general management and oversight, financial review, and approval of project investments.

233. KazTransGas Onimderi LLP 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 UN Framework Convention on Climate Change (UNFCCC); and
(iii) The Ministry of Innovation Development via the “Institute of Power Development and Energy Saving” regarding potential energy efficiency improvements in transport.

J. Other

234. This investment opportunity focuses on the construction of refueling infrastructure and capacity building. Therefore it does not lead to direct GHG emission reductions. However, indirectly it 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 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. The emission reductions are calculated in the national energy and transport model developed for Kazakhstan under Output 1 of RETA 8119. The methodology and emission factors for this calculation are documented in the TA document *Report on Nationally Appropriate Mitigation Actions (NAMAs) in Azerbaijan, Kazakhstan, and Uzbekistan.*

235. Realization of the suggested investment opportunity will provide the following co-benefits:

(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.

RETA 8119 Economics of Climate Change in Central and West Asia: Mitigation Component

Investment Concept Note
Construction of the Tuyabuguzskaya Small Hydropower Plant

Within the NAMA
Accelerating Deployment of Small-Scale Hydropower in Uzbekistan

ABBREVIATIONS AND ACRONYMS

ADB	Asian Development Bank
GHG	Greenhouse Gases
GOU	Government of Uzbekistan
HPP	Hydropower Plant
IRR	Internal Rate of Return
MAWR	Ministry of Agriculture and Water Resources
MOE	Ministry of Economy
MOF	Ministry of Finance
MRV	Monitoring, Reporting, and Verification
NAMA	Nationally Appropriate Mitigation Actions
NPV	Net Present Value
RETA	Regional Technical Assistance
SHP	Small-scale Hydropower Plant
tCO_2e	Tonnes of Carbon Dioxide Equivalent
TPES	Total Primary Energy Supply

CURRENCY EQUIVALENTS

(as of 15 June 2015)

1 $ = 2536.82 SUM

INVESTMENT OPPORTUNITY IN UZBEKISTAN

A. The Investment Opportunity

236. 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 small hydropower plant (SHP) which is under the jurisdiction of the Ministry of Agriculture and Water Resources (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.

B. Background

237. 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 energy for power generation. As presented in Table 1, 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.

Table 1: Potential Renewable Resource Yields in Uzbekistan

Resource	Annual Yield (billion kWh)
Biomass [a]	3.5
Hydropower [a]	20.9
Solar [a]	2,055
Wind [a]	4.6
Total Primary Energy Supply (TPES) in 2010 [b]	492

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. Forthcoming. Economics of Reducing GHG Emissions in the Energy and Transport Sectors of Azerbaijan, Kazakhstan and Uzbekistan: Options and Costs. Manila.

238. 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 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.[1]

C. Policy, Institutional, and Regulatory Framework for Small Hydropower

239. 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

[1] 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

plants on natural water streams and reservoirs. Uzsuvenergo is tasked with the construction and operation of HPPs at irrigation channels and other agricultural infrastructure.

240. On 5 May, 2015, the President of Uzbekistan 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 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 MW and rehabilitation of 33 existing HPPs that would increase their capacity to 1,973 MW.

241. 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 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.

D. NAMA to Accelerate Deployment of Small-Scale Hydropower

242. In support of Uzbekistan’s goal to promote small hydropower and increase renewable energy supply, the Asian Development Bank (ADB) has been working with the Ministry of Economy, MAWR, Uzbekenergo, and other stakeholders to design a NAMA that will help accelerate deployment of small-scale hydropower in Uzbekistan.

243. The goal of this NAMA is to expand small hydropower capacity in Uzbekistan by identifying the obstacles that have impeded successful implementation of prior programs and propose measures that will help remove these. This includes addressing institutional and legal ambiguities, conducting training and capacity building, and developing an updated atlas of small hydropower potential. The NAMA is also intended to facilitate increased public and private investment into SHPs.

244. The NAMA is expected to result in GHG emission reductions of about 918,715 tCO_2e per year by 2030.

E. Background on the Investment Opportunity

245. 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.

246. 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.

F. Technical Parameters

247. The proposed site for the SHP is the Tuyabuguz Water Reservoir in the Srednechirik region of Tashkent Oblast, 20 miles south of Tashkent (see Figure 1).

248. 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 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 generating capacity of 6.25 MW each.

249. 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.

250. 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.

Figure 1: Tuyabuguz Water Reservoir

Notes: The right photo of northern corner of Tuyabuguz reservoir shows the main spillway and the right (smaller) water discharge that feeds the irrigation system. This discharge is to be used for the construction of the SHP.
Source: Uzsuvenergo

G. Financial Parameters

251. The total cost of the project is estimated at $ 19.8 million, of which $ 9.84 million represents equipment costs.[2]

[2] Expressed as nominal cost.

252. 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.

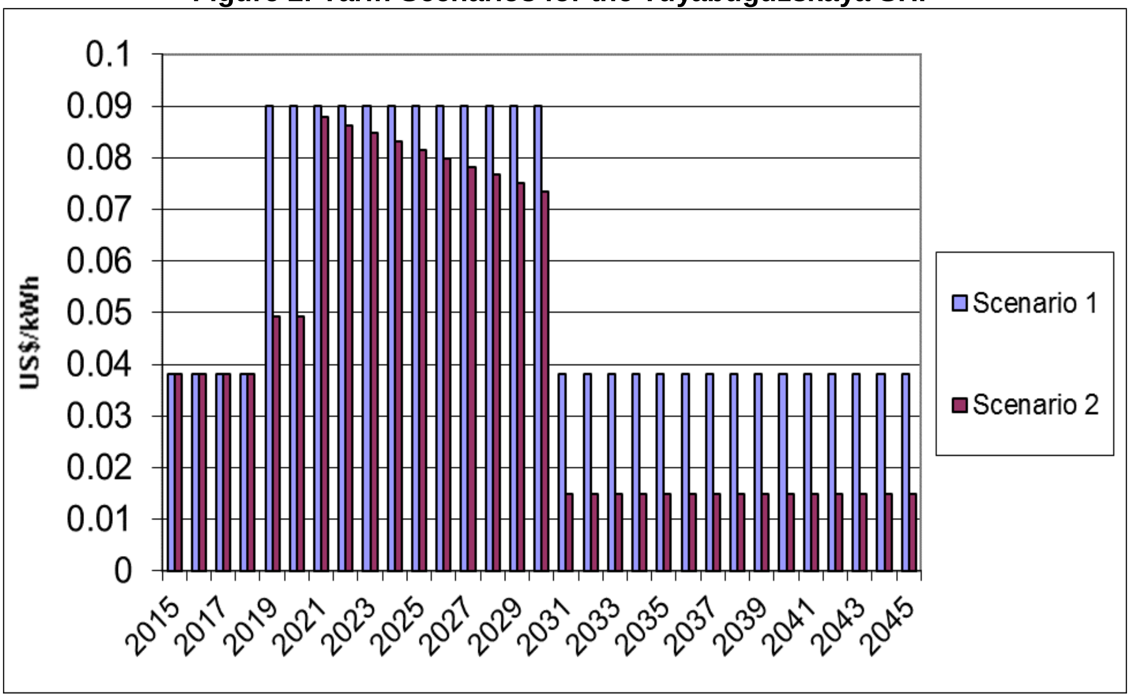
253. With the current electricity tariffs for Uzsuvenergo ($ 0.038) the project is not economically viable. At that tariff, the total revenue from electricity sales, without accounting for losses or any operating expenses, comes to $ 1.54 million while the repayment of principal alone (again, not accounting for interest and any other financing expenses) is $ 1.68 million. In order 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).

254. Scenario 1 in Figure 2**Figure 2** 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.

255. Scenario 2 in Figure 2 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’s no profit from project implementation.

256. 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.

Figure 2: Tariff Scenarios for the Tuyabuguzskaya SHP



257. Some potential adjustments may be made to this scenario to improve the viability of the Tuyabuguzskaya SHP:

(i) The financial analysis relies on a rough estimate of average SHP operating expenses and electricity production used by MAWR in its program for small hydropower development and expert estimates of auxiliary costs. A full feasibility study will be needed to analyze the cost of individual line items within each expense category and determine whether there are opportunities for optimization and cost cutting.

(ii) The estimated cost of the Tuyabuguzskaya SHP in terms of the amount of investment per MW of generating capacity is the lowest of all the small hydro plants in the MAWR Program for Small Hydropower (i.e., $ 1.6 million/MW). According to an international cost range of $ 2 million/MW to $ 4 million/MW, this is on the low side (OECD/IEA, 2010).[3] However, for the particular project site, which involves an existing dam and hydro-technical infrastructure and which has a limited need for new construction or adjustments, a technical solution at a lower cost may be still possible and should be analyzed.

(iii) The Tuyabuguzskaya SHP qualifies as a small enterprise and as such is entitled to a simplified tax scheme. This involves a unified tax of 5% levied against the total receipts for product sold (in this case, electricity). This particular tax may not be as beneficial to Tuyabuguzskaya SHP as it is for other small enterprises since for a number of years while the loan is being repaid the SHP will operate with very little or no profit and may therefore not be subject to income tax. Tuyabuguzskaya SHP would also be able to deduct depreciation and other expenses. If the designation as a small enterprise is optional and Tuyabuguzskaya SHP has a choice of tax regime, this choice may affect cash flow and should be optimized.

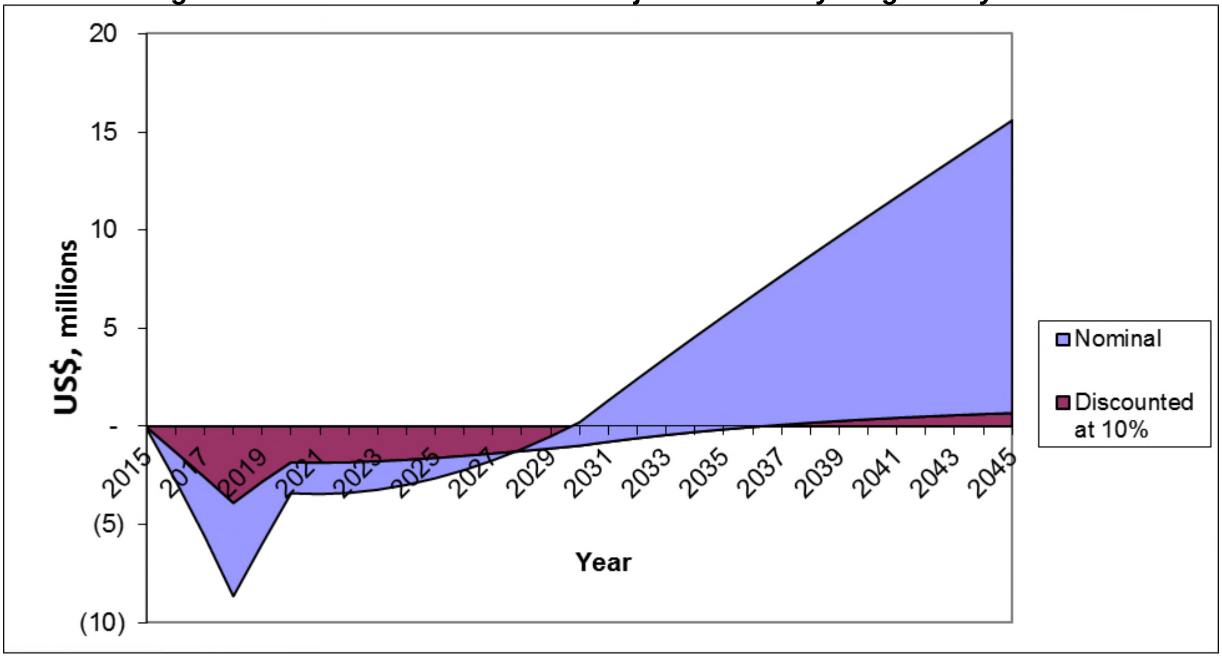
(iv) The estimated annual operating costs for the Tuyabuguzskaya SHP ($ 1.2 million) are higher than estimated average costs for a typical small hydro facility in developed countries ($ 1 million) (OECD/IEA, 2010).[4] A full feasibility study and increased training of staff resulting from the implementation of the NAMA may result in a downward estimate of these operating costs.

258. The cash flow of the project under Scenario 1 is shown in Figure 3.

[3] OECD/IEA, 2010. *Renewable Energy Essentials: Hydropower.* http://www.iea.org/publications/freepublications/publication/hydropower_essentials.pdf

[4] OECD/IEA, 2010. *Renewable Energy Essentials: Hydropower.* http://www.iea.org/publications/freepublications/publication/hydropower_essentials.pdf

Figure 3: Cumulative Cash Flow Projection for Tuyabuguzskaya SHP



Source: Abt Associates analysis.

H. Implementation Arrangements

259. 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.

260. 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.

I. Sensitivity Analysis and Risk Management

261. 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 2). The most sensitive parameters are, naturally, the tariff 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.

262. 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.

Table 2: Sensitivity Analysis of the Tuyabuguzskaya SHP 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

Note: Assumes a 10% discount rate
Source: Abt Associates analysis.

263. 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.

264. 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.

265. 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.

J. Other

266. 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.

267. 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 business, 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.

268. 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 M 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 GWh) with the approved Clean Development Mechanism emission factor for Uzbekistan (532 tCO_2 per GWh).[5]

[5] United Nations Framework Convention, Clean Development Mechanism. 2013b. ASB0003. Standardized Baseline: Grid Emission Factor for the Republic of Uzbekistan. Version 01.0
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