

# Uzbekistan Energy/Power Sector Issues Note



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## Acronyms and Abbreviations

<b>ADB</b>	Asian Development Bank
<b>AGRP</b>	Associated gas recovery plant
<b>APG</b>	Associated petroleum gas
<b>BBL</b>	Barrel of oil
<b>BCM</b>	Billion cubic meters
<b>BH</b>	Boiler house
<b>CACP</b>	Central Asia Center Pipeline
<b>CAPS</b>	Central Asia Power System
<b>CCGT</b>	Combined cycle gas turbine
<b>CDM</b>	Clean Development Mechanisms
<b>CERs</b>	Certified Emissions Reductions
<b>CHPP</b>	Combined heat and power plants
<b>CIS</b>	Commonwealth of Independent States
<b>CNCP</b>	China National Petroleum Corporation
<b>CPS</b>	Country Partnership Strategy
<b>DH</b>	District heating
<b>DSM</b>	Demand side management
<b>ECA</b>	Europe and Central Asia
<b>FY</b>	Fiscal year
<b>GGFR</b>	Global Gas Flaring Reduction Partnership
<b>GTL</b>	Gas-to-liquids
<b>GWh</b>	Gigawatt-hour
<b>HPP</b>	Hydropower plant
<b>IBRD</b>	International Bank for Reconstruction and Development
<b>IDA</b>	International Development Association
<b>IEA</b>	International Energy Agency
<b>IFI</b>	International Financial Institution
<b>IPP</b>	Independent Power Producer
<b>JOMEC</b>	Japan Oil, Gas and Metals National Cooperation
<b>JV</b>	Joint venture
<b>KNOC</b>	Korean National Oil Corporation
<b>KOGAS</b>	Korean Gas Corporation
<b>kW</b>	Kilowatt
<b>kWh</b>	Kilowatt-hour
<b>LPG</b>	Liquefied petroleum gas
<b>LRMC</b>	Long-run marginal cost
<b>MoE</b>	Ministry of Economy
<b>MTO</b>	Million tons of oil



<b>MTOE</b>	Million tons of oil equivalent
<b>MW</b>	Megawatt
<b>MWh</b>	Megawatt-hour
<b>NEA</b>	Nuclear Energy Agency
<b>OJSC</b>	Open joint-stock company
<b>PSA</b>	Production sharing agreement
<b>PV</b>	Photovoltaic
<b>TAGP</b>	Trans-Asia Gas Pipeline
<b>TCM</b>	Thousand cubic meters
<b>TPP</b>	Thermal power plant
<b>TSS</b>	Transmission substation
<b>UE</b>	Uzbekenergo
<b>UNG</b>	Uzbekneftegaz
<b>USC</b>	Uzbek Community Services
<b>UZS</b>	Uzbek soums
<b>UZEEF</b>	Energy Efficiency Facility for Industrial Enterprises Project in Uzbekistan
<b>WDI</b>	World Development Indicators
<b>WPP</b>	Wind power plant

## Executive Summary

### **Uzbekistan has a wealth of energy resources**

Uzbekistan has considerable primary energy resources, particularly fossil fuel. The proven reserves are estimated at about 1.8 trillion cubic meters (tcm) of gas, 0.6 billion barrels of oil, and 1.9 billion tons of coal. Most of the gas and oil reserves are located in the South-Western parts of the country. At current production rates, the proven reserves are estimated to last 31, 22 and 95 years respectively. The total undiscovered resources are estimated to be substantially larger.<sup>1</sup>

### **Natural gas is the main source of primary energy**

Natural gas is the primary fuel in the energy supply mix. It accounts for 82 percent of total primary energy supply followed by oil, hydro, and coal. In 2001-2010, production of gas increased by 13 percent reaching 59 billion cubic meters (bcm), driven by substantial investments in exploration and development of gas fields. Gas exports reached 14 bcm in 2010 – a six-fold increase from 2001.

Due to depletion of existing fields, production of oil reduced, reaching 87,000 barrels/day in 2010 - 50 percent decrease from 2001. As a result, Uzbekistan became a net crude oil importer since 2009.

### **The Government recognizes the significance of the energy sector**

Energy sector accounts for 7 percent of GDP and nearly 50 percent of capital investments.<sup>2</sup> Natural gas was the largest source of export revenue in 2010, accounting for 25 percent (US\$3.2 billion) of total commodity exports.

Given the importance of the energy sector to the economy, it is a key component of the Government's investment program for 2011-2015. The energy sector accounts for almost US\$34 billion, or 72 percent, of the Government's investment program. Sustainable development of the sector will help the Government realize the development agenda under the Economic Development Vision 2030, which aims to transform Uzbekistan into industrialized middle-income country by 2030.

Sustainable development of the power sector will be critical to support Uzbekistan's development vision because:

- Ensuring adequate and reliable electricity supply is a prerequisite for sustainable economic growth and development. Growth of industry and its competitiveness depends critically on reliable electricity supply.
- The power sector has significant untapped potential for energy

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<sup>1</sup> Undeveloped gas, oil and coal resources are estimated at 4 tcm, 5.7 billion barrels, and 5.7 billion tons respectively.

<sup>2</sup> As of 2011.

efficiency improvements in both the supply- and demand-side.

**The Government initiated a number of steps for development of the sector**

The Government initiated a number of important steps to support development of the energy sector: (a) secured foreign investments for exploration and development of new gas and oil fields; (b) initiated construction of gas-to-liquids (GTL) plants and developed fuelling stations and other infrastructure to support conversion of vehicles from gasoline to natural gas in order to reduce reliance on oil imports; (c) diversified gas exports by participating in the Central Asian Gas Pipeline Project; (d) secured financing for 42 percent (US\$3.5 billion) of the critical power sector investments required by 2020; (e) initiated programs aimed at modernization of the energy sector and reduction of energy intensity of the economy; (f) increased end-user electricity tariffs by an average of 12 percent per year during 2004-2012, enabling UE to cover operating costs; (g) completed the functional unbundling of generation, transmission, distribution, and dispatch; (h) and retained experts with good technical skills and experience required for adequate operation and maintenance of assets.

**Despite notable progress, the power sector faces a number of challenges**

Going forward, the power sector faces the following principal challenges:

1. Supply reliability, especially during winter season;
2. Demand- and supply-side energy inefficiencies;
3. Financing large required investments with minimum impact on state budget;
4. Limited diversification of electricity generation mix with near-complete dependence on gas; and
5. Vulnerability to climate change.

**Challenge #1: Supply reliability**

Supply reliability is becoming a country-wide problem caused by transmission bottlenecks as well as ageing and increasingly unreliable electricity generation plants. The country is estimated to have incurred economic loss of US\$52 million<sup>3</sup> in winter of 2010 because of unreliable supply. Nearly 40 percent of available generation capacity (11,900 MW) is past or will reach the end of service life by 2017. The demand for electricity and other energy resources is expected to increase in line with economic growth, thus, further challenging supply reliability. Supply shortages are estimated to rise, reaching around 20 percent of estimated consumption by 2020, if the Government does not make the required investments.

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<sup>3</sup> Calculated based on estimated un-served energy of 860 GWh and conservative estimate of the cost of un-served energy at US\$0.06/kWh.

**Challenge #2:  
Demand- and  
supply-side  
energy  
inefficiencies**

Low energy efficiency is an immediate and pervasive problem, but also a good opportunity to partially mitigate supply shortages. Uzbekistan has significant potential for improvements in supply- and demand side energy efficiency. Uzbekistan is the most energy inefficient country in Europe and Central Asia (ECA) region. These inefficiencies cost the economy at least 4.5 percent of GDP every year. The following specific energy efficiency challenges need to be addressed:

- **Demand-side energy efficiency.** Energy use per unit of GDP is 2.6 times higher than the average for ECA. Industry is the largest consumer of electricity and also one of the largest sources of energy inefficiency due to use of outdated and energy-inefficient technology. Agriculture is also one of the most energy intensive sectors of the economy due to reliance on inefficient water pumping infrastructure.
- **Efficiency of gas-fired power plants.** In 2010, the country lost US\$1.2 billion (2.6 percent of GDP) in potential gas export revenues or 26,000 GWh of additional generation due to low efficiency of gas-fired plants, which is 40 percent lower than that of modern thermal plants.
- **Efficiency of electricity transmission and distribution (T&D).** Total electricity losses are estimated at 20 percent of net generation with the cost of excess losses at US\$340 million (0.8 percent of GDP).
- **Gas flaring.** Uzbekistan flared 1.8 bcm of gas in 2011 – the annual consumption of Armenia or nearly 3 percent of the country’s total natural gas production - with an estimated value of US\$500 million (1.1 percent of GDP).

**Challenge #3:  
Financing large  
required  
investments  
with minimum  
impact on state  
budget**

The Government estimates the gas and oil sector to require US\$28 billion of investments by 2015 and the power sector – US\$8.4 billion by 2020.

Gas and oil sector investments are required to explore and develop new oil and gas fields, expand oil recovery from existing fields, construct new GTL plants, and rehabilitate oil and gas infrastructure, including refineries, gas transmission and distribution network. The Government plans to finance most of the gas and oil investments by attracting foreign investors.

The power sector investments are required for replacement of ageing and construction of new assets to improve supply reliability and meet increasing demand. The Government has already secured US\$3.5 billion (42 percent of the required amount) and US\$2 billion worth of projects are under preparation and implementation. However, additional US\$4.9 billion will be required for which

financing has not yet been secured.

Power sector investments have historically been publicly funded. Predominantly public financing of power sector investments will not be feasible going forward and is not a sustainable economic strategy. The Government will need to explore other options, including ways to increase the sector's capacity to generate more cash internally and attract private sector investors. However, current level of tariffs limits UE's ability to finance a larger share of required investments from own sources. The current average electricity tariff of US\$0.05/kWh allows UE to fully recover operating and maintenance costs, however, not sufficient to increase financing of investments from own sources.

The current tariff is estimated to be 50 percent lower than long-run cost of supply of US\$0.11/kWh.<sup>4</sup> In 2006-2011, UE invested around US\$400 million in energy projects from own funds, whereas additional investment needs with unsecured financing are estimated at US\$4.9 billion.

**Challenge #4:  
Limited  
diversification of  
generation mix**

Gas-fired thermal plants account for 82 percent of total electricity generation, consuming 12 bcm or 20 percent of the gas produced in the country. This results in missed opportunities for higher value gas exports, limited system reliability and load management issues because of a lack of capacity designed to serve peak load.

**Challenge #5:  
Vulnerability to  
climate change**

The power sector is vulnerable to long-term climate change impacts. If those potential impacts are not taken into account when planning infrastructure investments, they will impose costs on the economy. Climate change may impact the power sector through: (a) reduced electricity generation at thermal power plants; (b) greater variability in generation by hydropower plants; (c) larger losses in transmission and distribution networks due to increasing temperatures and increased incidence of physical damage to infrastructure from climate change instigated events (e.g. mudflows, landslides); and (d) increased summer demand for air conditioning.

**Immediate  
actions to start  
addressing the  
challenges**

The Government can immediately start implementing a number of key actions and programs to address the identified challenges:

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<sup>4</sup> Bank team estimate.

Challenges	Immediate actions to address the challenges
Supply reliability, especially during winter season	<ul style="list-style-type: none"> <li>▪ Prioritize T&amp;D infrastructure to eliminate bottlenecks and reduce distribution losses</li> <li>▪ Use opportunities for regional trade to reduce the supply shortages</li> <li>▪ Accelerate improvement of demand- and supply-side energy efficiency</li> </ul>
Demand- and supply-side energy inefficiencies	<ul style="list-style-type: none"> <li>▪ Bolster agricultural and industrial energy efficiency</li> <li>▪ Scale up efforts targeting energy efficiency improvements in residential and public sectors</li> </ul>
Financing large required investments with minimum impact on state budget	<ul style="list-style-type: none"> <li>▪ Pursue contract-based Independent Power Producer (IPP) projects to attract private capital without major changes to existing structural and institutional arrangements of the sector</li> <li>▪ Improve prioritization of investments based on sound cost-benefit analyses</li> <li>▪ Explore options to increase UE revenues through efficiency improvements and additional tariff increases to enhance the borrowing capacity</li> </ul>
Limited diversification of electricity generation mix with near-complete dependence on gas	<ul style="list-style-type: none"> <li>▪ Conduct sound generation options study to plan for diversification of generation mix to utilize renewable energy (e.g. small hydro, solar, wind) and coal resources</li> <li>▪ Carefully analyze tradeoffs when converting the existing gas-fired plants to coal: <ul style="list-style-type: none"> <li>- New coal-fired plants are 20 percent more efficient than those converted from gas-fired</li> <li>- Coal-fired plants are more efficient and reliable when run as base-load</li> <li>- Construction of new coal-fired Combined Heat and Power Plants (CHPP) close to industrial centers with heat demand can ensure higher efficiency of generation</li> <li>- Technical and economic viability of carbon capture from coal plants and sequestration to enhance oil and gas recovery at existing fields</li> </ul> </li> <li>▪ Use opportunities for electricity imports</li> </ul>

**Solutions to challenge #1: Invest in T&D and use opportunities for regional trade**

Supply reliability can be improved by investing in improvements of transmission and distribution lines and through more extensive seasonal trade with neighbors.

- **Prioritize T&D infrastructure.** UE has been investing in the transmission system since 2000, gradually adding and rehabilitating transmission lines and substations between major power plants and load centers. Further investments can help improve supply reliability. Around US\$1.3 billion in investments are needed by 2020, including development and rehabilitation/modernization of transmission lines, substations, switchyards and new distribution-level infrastructure, such as bulk meters and advanced electrical meters for individual customers. Investments in distribution infrastructure should also focus on reducing technical losses, which will help the country to save around US\$7.2 billion (0.5 percent of cumulative GDP) over the next 20 years. The Government may consider implementing a detailed study to plan for transmission network expansion, identify the transmission network bottlenecks and assess the investment needs.
- **Use opportunities for regional trade.** Currently, Uzbekistan's trade within Central Asia Power System (CAPS) does not exceed 2 percent of net domestic demand per year. Importing excess electricity from hydro-rich neighbors during summer and daily trading during winter months can create economic savings of at least US\$60-70 million per year. The trading could allow deferring construction of around 500 MW of new capacity.

**Solutions to challenge #2: Expand demand-side interventions and invest in supply-side efficiency**

The Government should consider initiating the following key actions to further improve demand and supply-side energy efficiency.

- **Bolster industrial and agricultural energy efficiency.** The Government should continue its efforts to improve energy efficiency of industry and agriculture. Metallurgy, production of construction materials, mining are estimated to have the highest potential for electricity savings in the industrial sector. Even 15 percent reduction of electricity consumption in industry can save the country US\$7.7 billion over a 20-year period (1.2 percent of cumulative GDP). Improvements in energy efficiency of irrigation pumps can substantially reduce electricity consumption in agriculture since irrigation pumps account for 70 percent of electricity consumption of the sector. 25 percent improvement in agricultural energy efficiency can save the country US\$4.6 billion over a 10-year period (0.3 percent).
- **Scale up efforts targeting energy efficiency improvements in residential and public sectors.** The Government should scale-up its efforts to improve demand-side energy efficiency in other sectors, including residential and public. To that end, the

Government needs to conduct an assessment of economically and financially viable energy efficiency potential in those sectors.

- **Invest in supply-side energy efficiency.** Building sufficient generation capacity is an important challenge, but it is also an opportunity. Investments in modern and efficient generation plants, would allow Uzbekistan to export gas, which is otherwise wasted in old and comparatively inefficient plants that could be used to meet the peak load.

Portion of increased gas export revenues could be used to finance much needed power sector investments and mitigate the impact of rising electricity prices on the poor as the Government starts gradually increasing tariffs to the level of long-term supply costs. This will complement above mentioned efficiency improvements in the T&D infrastructure to reduce losses.

Capturing and utilizing or exporting the gas wasted due to flaring could provide significant economic and environmental benefits. To that end, the Government should conduct assessment of technical and economic viability of various options for flared gas capture and utilization at several gas fields with large flare volumes.

### **Solutions to challenge #3:**

**Improve prioritization, try IPPs, increase UE cash flows**

The Government can secure additional financing for power sector investments by initiating a number of actions:

- **Introduce contract-based independent power producer (IPP) projects.** The government can attract private financing into the sector by implementing IPP type projects, which can be regulated through contracts. The Government may start with few IPP projects to test the market and design rules for large scale future private participation. Specifically, competitive international tenders for Build-Operate-Transfer (BOT) or Build-Own-Operate (BOO) arrangements can attract private investment, while not requiring major changes to institutional and structural arrangements for UE as would the privatization of assets. However, attracting competitive and high-quality bids will require better disclosure and transparency in the sector (in particular, better information about the operating and financial performance of UE and its subsidiaries) as well as improvement of the Government capacity to prepare and implement such tenders.
- **Improve prioritization of investments.** The government should prioritize investments through sound techno-economic and feasibility studies to select the projects with highest net economic benefits to the country within existing funding constraints.
- **Explore options to increase UE revenues.** Electricity tariff increases, coupled with operational improvements (e.g. loss reduction), will allow UE to finance large share of required



investments through its cash flows and improve borrowing capacity of UE. At current level of losses and tariff increase equal to the rate of projected average annual inflation,<sup>5</sup> UE will be able to finance only around 30 percent (US\$1.5 billion) of investments with unsecured financing by 2020.<sup>6</sup> However, if annual tariff increase exceeds the projected inflation rate by 4 percent and losses reduce from 19 to 13 percent, UE would be able to finance up to 50 percent (US\$2.5 billion) of investments with unsecured financing. The potential tariff increases should be coupled with: (a) tariff structure improvements to promote efficient use of electricity, and (b) appropriate social assistance mechanisms to mitigate the impact on vulnerable groups of consumers.

**Solutions to  
challenge #4:  
Start planning  
for  
diversification**

The Government should consider carrying out a planning study to determine the optimal electricity generation mix in order to reduce reliance on gas for domestic generation and save it for higher value exports. There are opportunities for diversifying into renewables (e.g. wind and solar) and more efficient coal-fired generation. However, decisions about diversification should carefully consider a number of important technical, economic and environmental factors, including possibility of importing summer electricity surplus from neighboring countries.

**Solutions to  
challenge #5:  
Start adapting to  
climate change**

The Government should consider a number of adaptation measures that can be introduced over time to enhance power sector resilience against climate change impacts: (a) diversification of electricity generation mix; (b) improvement of energy efficiency; (c) improvement of water resource management; (d) improvement of energy asset maintenance and disaster risk management; and (e) improvement of knowledge and strengthening of key responsible institutions.

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<sup>5</sup> 11 percent in 2013-2017 and 5 percent in 2018-2019; the projections draw upon the IMF projections of Consumer Price Index in Uzbekistan; World Economic Outlook, IMF, April 2012; calculations are made assuming UZS2,000 per 1US\$ exchange rate in 2013-2020.

<sup>6</sup> Assuming maximum debt-to-equity ratio of 70:30.

# Introduction

Uzbekistan is endowed with considerable primary energy resources, particularly fossil fuels. The country has experienced rapid economic development over the past decade and is aiming at even higher growth targets in the future.

Careful management of energy resources, provision of reliable supply and efficient end-use are critical for supporting Uzbekistan's economic growth and improving the welfare of its citizens. The energy sector should be conducive to economic growth and development and not become a constraint due to increasing operational inefficiencies, unreliable supply and high energy costs. The country is likely to face significant energy related challenges in the short- and long term. Therefore, it will be important that the Government, energy sector entities and donors recognize these challenges early on and work together to find appropriate solutions.

This Note focuses on the energy/power sector in Uzbekistan with the purpose of identifying some of the key issues faced by the sector and outlining potential solutions. In particular, the Note aims to inform the Government thinking by providing input on priorities in the sector. The Note also outlines potential solutions the Government may want to consider to address the identified challenges in the short and longer time and highlights the areas where the Government can start acting immediately.

The analysis is based on Government information and data provided during preparation of the Bank's investment lending operations, other analytical work as well as data/information collected from public sources.<sup>7</sup>

The Note is structured as follows:

- **Section 1** discusses the importance of the energy sector to the economy and provides an overview of the sector.
- **Section 2** provides a more detailed overview of the power sector.
- **Section 3** identifies the principal challenges in the power sector.
- **Section 4** proposes potential solutions to address these challenges.
- **Section 5** outlines a potential role for the World Bank in supporting the Government to address power sector challenges.

The appendices provide information supporting the descriptions, analysis, and recommendations in Sections 1 through 5.

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<sup>7</sup> Key energy sector data sources include State Statistics Committee of Uzbekistan; web-sites of Uzbek Government Agencies and energy sector companies; International Energy Agency; US Energy Information Administration; BP Statistical Reviews of World Energy; and Business Monitor International; and the reports of donor-financed studies.

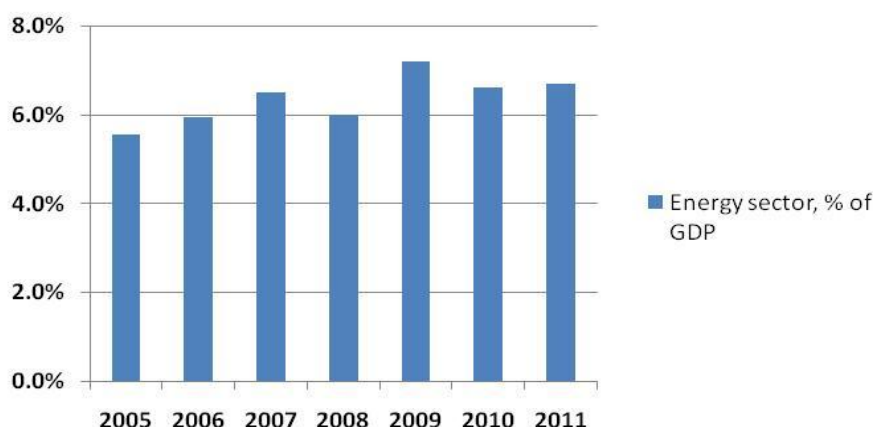
# 1 Economic Importance of the Energy Sector and Overview of the Gas, Oil and Coal Sectors

## 1.1 Energy Sector in Macroeconomic Context

The energy sector is critical for Uzbekistan's economic growth and development given the long-term economic development vision of the Government. Specifically, the Government is pursuing an industrial growth and export-led development strategy (to be formulated into Uzbekistan's Economic Development Vision 2030). The objective is to transform Uzbekistan into an industrialized middle-income country with per capita income of US\$6,500 by 2030 and US\$8,500 by 2040.<sup>8</sup> To that end, in 2009, the Government embarked upon US\$43 billion, six-year (2009-14) Industrial Modernization and Infrastructure Development Program. The energy sector is estimated to account for US\$33.7 billion or about 72 percent of the total planned investments. The program comprises over 500 large investment projects and aims to increase the industry's share of GDP from 24 percent in 2010 to 28 percent in 2015.

The energy sector is a major contributor to GDP and the largest export revenue generator. In 2010, the energy sector accounted for 6.7 percent of GDP and 27.7 percent of industrial output (US\$3.0 billion). In 2010, energy exports (predominantly natural gas) accounted for 25 percent of total commodity exports (around US\$3.2 billion).<sup>9</sup>

**Figure 1.1: Energy sector share of GDP**



Source: World Bank estimate based on data from State Statistics Committee.

The sector also accounts for a large share of total capital investments in the country. In 2009, capital investments (including Foreign Direct Investments) in the energy sector were estimated at US\$1.7 billion<sup>10</sup> or 49.5 percent of total capital investments,

<sup>8</sup> Per capita GDP in 2011 was estimated at US\$1,560 in current US\$.

<sup>9</sup> Uzbekistan Almanach 2011, Centre for Economic Research, Tashkent, 2012. Main Indicators of Development of Fuel and Energy Complex of Uzbekistan for 2001-2010, Informational and Analytical Review, Institute for Forecasting and Macroeconomic Research, Tashkent 2012.

<sup>10</sup> Calculated at official average annual 2009 nominal exchange rate: US\$1= UZS1498.

compared to 33.8 percent in 2005. Currently, the vertically integrated companies in the sector - Uzbekneftegaz and Uzbekenergo - are implementing over 70 major investment projects with a total value of more than US\$23 billion.<sup>11</sup> In 2010, foreign direct investments in oil and gas were estimated at US\$495 million.<sup>12</sup>

## 1.2 Reserves and Primary Fuel Supply

Uzbekistan has significant fossil fuel reserves with natural gas accounting for 70 percent in terms of energy content. Fossil fuels are currently the primary sources for electricity, heating and other uses in Uzbekistan.

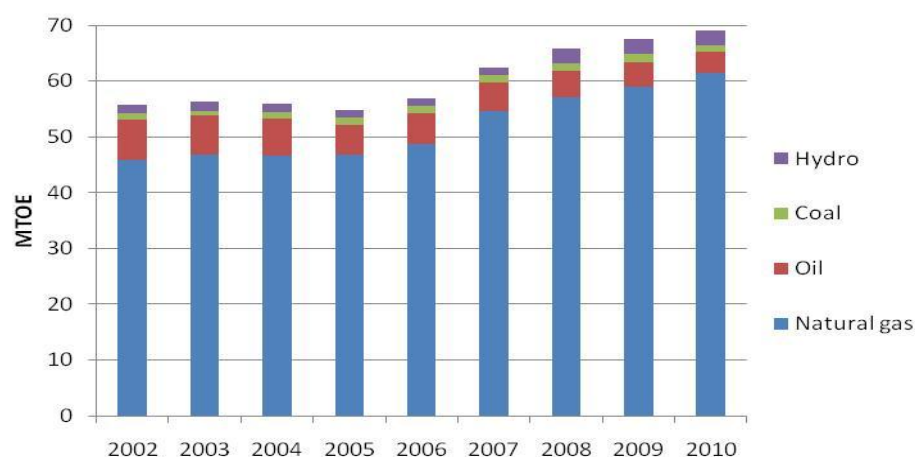
**Table 1.1: Fossil Fuel Energy Reserves**

Resource	Proven reserves	Estimated undiscovered resources
Natural gas	1,841 bcm	4,000 bcm
Oil	594 million bbl	5,700 million bbl
Coal	1.9 billion tons	5.7 billion tons

Source: World Bank team estimate based on UNG web-site, Government of Uzbekistan portal, BP Energy Report 2011, Energy Information Agency and other public sources; Business Monitor International, Uzbekistan Oil & Gas Report, Q3 2012.

Natural gas prevails in the energy supply mix. Specifically, it accounts for 82 percent of total primary energy supply while oil and coal contribute 10 percent and 3 percent, respectively. Renewable energy resource potential<sup>13</sup> is estimated to be significant, but, with the exception of hydropower, is not yet exploited on a large scale.

**Figure 1.2: Primary Energy Supply**



Source: BP Statistical Review of World Energy, June 2011.

<sup>11</sup> UNG web-site, 2012; Bank team estimates based on data provided by UE in 2011; more than US\$3 billion financed by companies' own funds.

<sup>12</sup> Turkish weekly, Oil and gas sector as basis of Uzbekistan's energy independence, 17 June 2011.

<sup>13</sup> Renewable energy potential is discussed in Section 3.

## 1.3 Gas Sector

### Structure, Legal and Regulatory Framework

The gas and oil sectors in Uzbekistan are run by the vertically integrated state-owned monopoly, the National Holding Company “Uzbekneftegaz” (UNG). UNG, through its subsidiaries, controls all major down- and upstream activities, including gas and oil exploration and production, processing, transmission, distribution and storage (see Appendix B for details).

Exploration and production of gas and oil in Uzbekistan are mainly regulated by the Mining Law, the Concessions Law, the Law on Natural Monopolies and the Law on Production Sharing Agreements. Foreign investments in the sectors are primarily regulated by the Law on Foreign Investments, the Law on Guarantees and Measure on Protection of Foreign Investor and the Law on Investment Activity, and the Law on Production Sharing. Presidential decrees complement the regulatory framework in the oil and gas sector.<sup>14</sup>

Most exploration and production investments by foreign investors take the form of Joint Ventures (JV) or Production Sharing Agreements (PSA). In order to attract more foreign investments, the Government has introduced some incentives, such as tax concessions, to companies involved in exploration or production of hydrocarbons. For instance, companies engaged in JV for exploration and production of hydrocarbon are granted a 7-year exemption from the corporate income tax as well as exemptions from profit taxes adjusted for the stake in JV.<sup>15</sup>

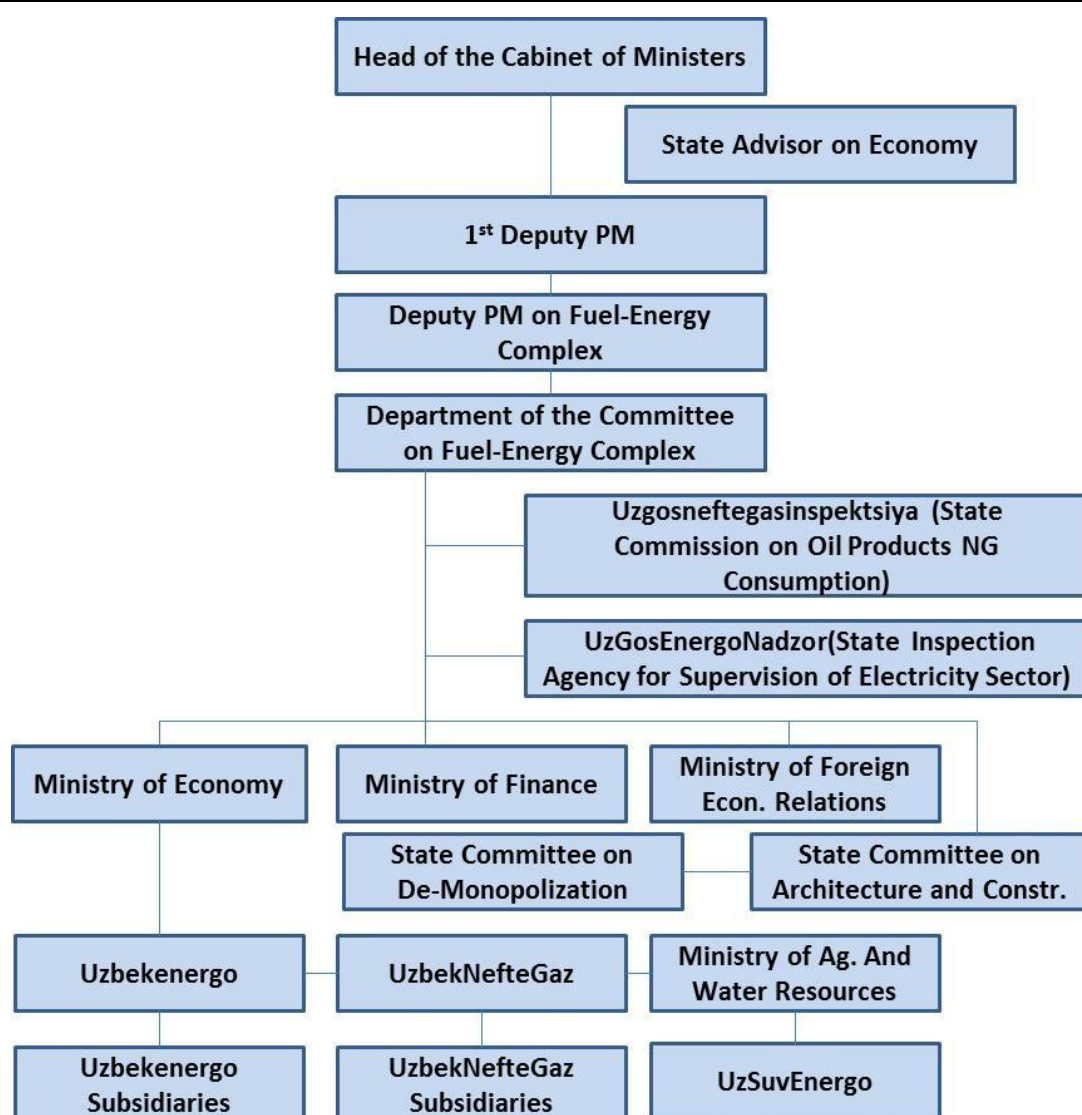
Multiple government agencies and organizations regulate the energy sector. There are some common entities involved in the regulation of the power, gas and oil sectors. Figure 1.3 shows the structure of government regulation in these sectors in Uzbekistan.

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<sup>14</sup> Energy Charter, Uzbekistan, In-Depth Review of the Investment Climate and Market Structure in the Energy Sector, 2005.

<sup>15</sup> Global Legal Group, the international comparative legal guide to gas regulation, 2011.

**Figure 1.3: Government Entities Regulating Uzbekistan's Energy Sector**



Source: Bank team.

### Government Priorities in Gas and Oil Sectors

The key objective of the Government is to ensure reliable supply of gas and oil in order to meet domestic demand as well as to expand and diversify exports. In order to achieve the above objective, the Government identified the following key priorities for the oil and gas sectors:

- **Expanding proven gas and oil reserves** by increasing public financing as well as promoting foreign investments in exploration and development of new oil and gas fields.
- **Increasing energy efficiency** through modernization of gas and oil production, processing and transport infrastructure, reduction of gas flaring, as well as increasing recovery rates from existing oil and gas fields with priority attention paid to depleting and hard-to-reach fields.

- **Ensuring financial soundness of the sector and improving the legal and regulatory framework** to promote foreign investments in the sector.
- **Increasing and diversifying gas exports** by improving energy efficiency of gas-fired generation and gradually substituting gas with coal for domestic consumption. In particular, the Government plans to increase the share of coal in the energy balance from 3 percent in 2011 to 11 percent by 2016. The Government is also planning to intensify participation in regional energy projects to further diversify gas exports.
- **Reducing environmental impacts** through reduction of oil and gas losses/leaks, reduction of gas flaring and further improvement of supply and demand-side energy efficiency.

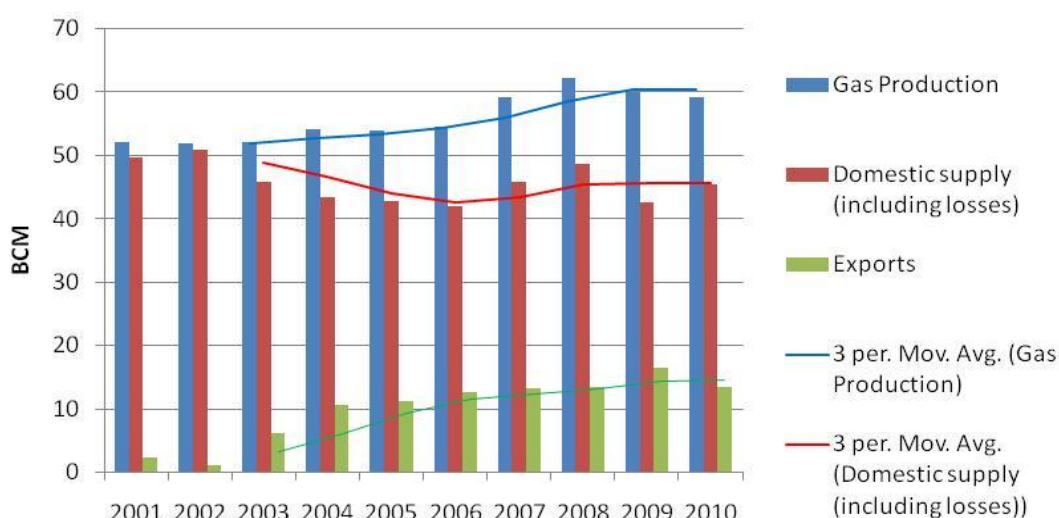
### Reserves, Supply and Demand

As of 2010, the proven gas reserves were estimated at 1,841 bcm (0.8 percent of global gas reserves).<sup>16</sup> Undiscovered gas resources are estimated at 4 tcm with exploratory work underway at some potential locations.

Uzbekistan is the second largest natural gas producer in the ECA region, after Russia. In 2001-2010, production of natural gas increased by 16 percent, or 8 bcm, reaching 59.1 bcm in 2010. This increase is mainly a result of significant domestic and foreign investments targeted at enhancing gas recovery from existing fields and exploring and developing new fields.

Over 95 percent of gas production is concentrated in 12 deposits, particularly in the South-Western regions of the country. Figure 1.4 presents summary data for gas production and consumption in Uzbekistan in 2001-2010.

**Figure 1.4: Gas production and consumption data**



Source: BP Statistical Review of World Energy, June 2011.

<sup>16</sup> BP Statistical Review of World Energy, June 2011.

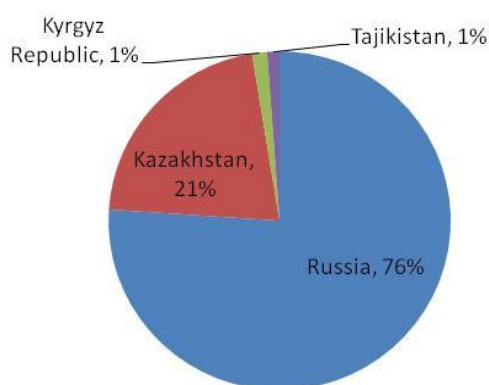
Total domestic supply in 2010 amounted to 45.5 bcm, including losses estimated at 2.7 bcm (6 percent of total production), reflecting the poor condition of some of the assets. Residential consumers and industry are the largest gas consumers in the country accounting respectively for 50 and 27 percent of total consumption respectively.

The residential sector is using gas primarily for cooking, water and space heating purposes. 85 percent of urban and 79 percent of rural households are connected to the gas supply network. More than 720,000 households in rural areas use liquefied petroleum gas (LPG) in LPG bottles to meet their domestic energy needs, particularly for cooking.<sup>17</sup>

Electricity generation accounts for the largest share of industrial consumption. Since the mid-1960s, the country's reliance on natural gas for generation of electricity has been increasing. In 2010, gas-based electricity generation accounted for 88 percent of total generation. Other major industrial consumers include chemical plants, construction material producers and smelters.

Uzbekistan is a net exporter of natural gas. In 2010, gas exports were estimated at 14 bcm, which corresponds to a six-fold increase over 2001. Historically, Russia accounted for the largest share of gas exports. In 2002-2010, gas exports to Russia constituted at least 70 percent of total gas exports. During the same period, sales to Kyrgyz Republic and Tajikistan significantly reduced due to decrease in demand resulting from price increase and disputes about terms and conditions of the gas supply contracts. However, the country has made some progress with diversifying gas exports. Specifically, with commissioning of the first two sections of the Central Asian Gas Pipeline in 2009 and 2011, Uzbekistan plans to export up to 5 bcm/year of gas to China starting from 2013, which could gradually reduce the share of gas exports to Russia to 44 percent and increase the exports to the South to 27%.

**Figure 1.5: Gas export structure in 2010**



Source: World Bank team.

<sup>17</sup> Bank team estimate.



Domestic supply is projected to increase by 33 percent, reaching 60 bcm by 2021, while the Government plans to increase exports by 220 percent to reach 45 bcm by 2021.

### Gas Tariffs

The country has a two-tier gas tariff system – regulated prices for domestic gas consumers and international netback prices for exports based on negotiations with buyers. For domestic sales, prices are regulated by the Ministry of Finance. UNG calculates and submits on a yearly basis the proposed tariffs for various domestic consumer groups for approval of the Ministry of Finance.

**Table 1.2: Gas Tariffs in 2011**

Consumer Group	US\$/ tcm
Metered residential consumers <sup>18</sup>	47
Public, commercial, and industrial consumers	42-50
UE and other wholesale consumers	62
Exports	240-300

Source: UNG web-site.

### Infrastructure

The country has extensive gas production, storage and supply infrastructure. The main gas processing plants are the Mubarek and Shurtan Gas Processing Plants, which process around 24 bcm and 20 bcm of gas per year respectively.

The largest gas storage facility is the underground storage at Kodzhaabad (utilized volume – 0.9 bcm, maximum – 1.0 bcm), which was completed in 1999 at a cost of US\$72 million. The facility is located in the Far East region of Andijan and supplies the industrial center in Fergana Valley. In addition, there are two smaller size underground gas storage facilities in the Bukhara (South-Western part of the country) and Kokand areas (Eastern part of the country), which were built to regulate seasonal fluctuations of gas demand.<sup>19</sup>

Gas transportation system consists of 13,000 km of high-, medium- and low- pressure transmission and distribution pipelines and over 250 compressor stations. Uzbekistan is also a major transit country for several international gas pipelines, including the Central Asia-Centre Pipeline to Russia and the new Central Asia Gas Pipeline.

Uztransgaz, a subsidiary of UNG, owns and operates the entire system of natural gas transmission pipelines as well as storage facilities with the exception of Uzbekistan-China section of the Central Asia-China pipeline, which is 50 percent owned by the Chinese.

<sup>18</sup> There are also tariffs for unmetered residential customers depending on the number and type of gas-consuming equipment and the number of residents.

<sup>19</sup> Energy Charter Secretariat, In-Depth Review of the Investment Climate and Market Structure in the Energy Sector, 2005.

Third-party access for transport and distribution infrastructure is determined by Uztransgas based on the terms regulated by the Antimonopoly Agency and tariffs approved by the Ministry of Finance.<sup>20</sup>

Gas exports are supported by the following major gas pipelines: Central Asia-Center Gas pipeline (capacity of 80 bcm/year), Central Asia Gas Pipeline (capacity of 30 bcm/year), Bukhara-Urals pipeline (capacity of 55 bcm/year) and the Bukhara-Tashkent-Bishkek-Almaty pipeline.

## **1.4 Oil Sector**

### **Structure, Legal and Regulatory framework**

The oil sector is run by UNG and is regulated mostly under the same legal and regulatory framework as the gas sector. Please see Section 1.3 and Appendix B.

### **Reserves, Supply and Demand**

As of 2010, Uzbekistan was estimated to have 594 million bbl of proven oil reserves.<sup>21</sup> Over 60 percent of proved oil fields are located in the Bukhara-Kiva region (Southern and South-Western parts of the country), including the Kokdumalak field, which accounts for about 70 percent of the country's oil production.<sup>22</sup> The country is estimated to have 5.7 billion bbl of unproved oil reserves with exploratory work underway at some potential locations.

In 2010, Uzbekistan produced on average 87,000 bbl of oil per day, a 51 percent decline compared to 2001. Decrease in oil output is due to lack of investments in old fields, ongoing depletion and low recovery rates (estimated at 28 percent) at existing production fields. Figure 1.6 summarizes oil production and consumption in Uzbekistan in 2001-2010.

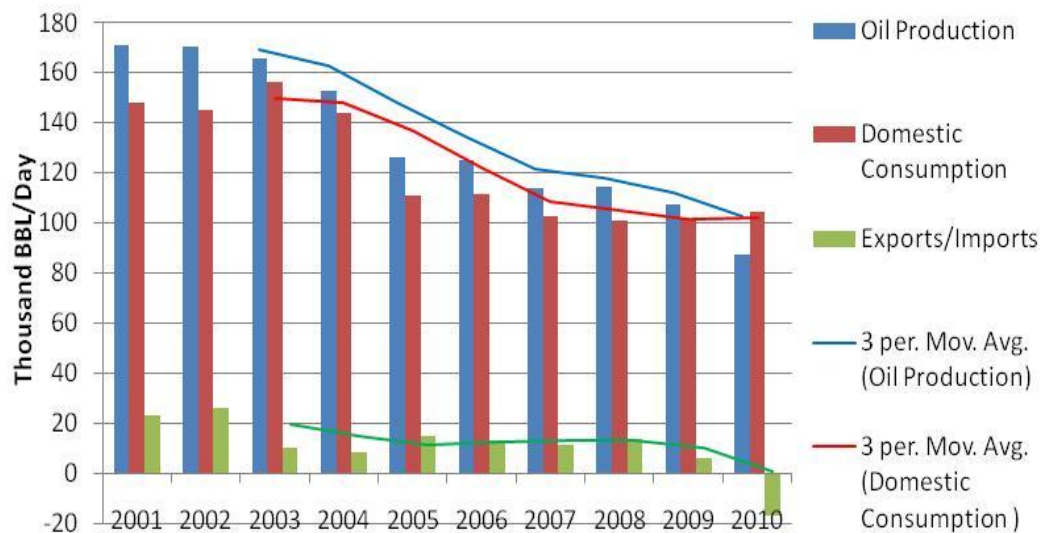
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<sup>20</sup> Global Legal Group, the international comparative legal guide to: gas regulation 2011.

<sup>21</sup> Business Monitor International, Uzbekistan Oil & Gas Report, Q3 2012.

<sup>22</sup> Business Monitor International, Uzbekistan Oil & Gas Report, Q2 2011.

**Figure 1.6: Oil Production and Consumption**



Source: BP, BP Statistical Review of World Energy, June 2011. Accessed May 2, 2012, <http://www.bp.com/sectionbodycopy.do?categoryId=7500&contentId=7068481>

Oil consumption in 2010 was at 105,000 bbl/day, with transport sector accounting for about 57 percent, residential sector - 25 percent, and industry - 17.4 percent. While oil consumption is estimated to increase by 190 percent by 2021, domestic production is projected to rise by only 40 percent.<sup>23</sup>

To decrease import dependency, Uzbekistan plans to convert more gas to oil products by constructing a GTL plant and promoting conversion of vehicles from gasoline to gas-fired. The Shurtan GTL plant will be located in the Kazhkadarya region and is intended to be completed by 2017. It is expected to convert 3.4 bcm of natural gas to 12.3 million bbl of oil products per year.<sup>24</sup>

At the end of 2011, the country had 16 percent of total registered vehicles (around 310,000) running on liquefied natural gas, with plans to reach 70 percent of the total fleet. Such conversion is driven by two factors. First, the costs per km fuel for gas-fired vehicles are 2.5 times lower than for gasoline-fired. Second, supporting infrastructure (fuelling station, vehicle conversion and service centers) is rapidly expanding with over 200 fuelling stations countrywide. The Government plans to build additional 340 fuelling stations by 2015.<sup>25</sup>

### Infrastructure

Uzbekistan has two major refineries: Fergana/Alty-Aryk and Bukhara with total available capacity of 194,288 bbl/day. The Fergana/Alty-Aryk facility was formed by the merger of Fergana refinery (commissioned in 1958) and Alty-Aryk refinery (commissioned in 1906). It was rehabilitated in late 1990s and has a total capacity of

<sup>23</sup> Business Monitor International, Uzbekistan Oil & Gas Report, Q3 2012.

<sup>24</sup> Business Monitor International, Uzbekistan Oil & Gas Report, Q3 2012.

<sup>25</sup> "Three hundred and ten thousand vehicles and growing." [www.naturalgasglobal.com](http://www.naturalgasglobal.com), accessed on Aug. 1, 2012.

114,288 bbl/day. The refinery produces gasoline, LPG, fuel oil (including aviation fuel), sulphur and solvents.

Bukhara refinery has a capacity of 50,000 bbl/day expandable to 110,495 bbl/day. The key products of the refinery are gasoline, diesel, LPG and fuel oil (including aviation fuel). The refinery can process a wide range of crudes oils, ranging from condensate to heavy oil. Condensate is supplied by the oil pipeline from the Kokdumalak field and in smaller volumes by rail from the Khauzak gas field.

With declining oil production in recent years, Uzbekistan is becoming increasingly dependent on crude imports to supply its domestic oil refineries. As a result, the refineries operate at only 60 percent of their capacity.<sup>26</sup> There are two major oil pipelines: Omsk-Skymkent-Bukhara and Shymkent-Tashkent Products Pipeline. The first pipeline is used to transport oil from Russia and Kazakhstan and the Shymkent-Tashkent pipeline starts at the refinery in Kazakh city of Shymkent and runs to the capital city of Tashkent. It is used for small-scale gasoline and oil imports.

## **1.5 Coal Sector**

### **Structure, Legal and Regulatory Framework**

Uzbekugol is the national vertically integrated monopoly coal company owned by UE. The company operations are overseen by a Supervisory Board, while the Executive Body is responsible for daily operations and management of the company.

Exploration and production of coal in Uzbekistan is primarily regulated by the Mining Code, Law on Concession, and the Law on Natural Monopolies.

### **Government Priorities in Coal Sector**

The key objective of the Government is to increase coal production from the current level of 3.6 million tons per year to 17 million tons by 2020. To that end, the Government is developing a phased program for coal industry development to be implemented in 2011-2020.

### **Reserves, Supply and Demand**

As of 2010, Uzbekistan was estimated to have 1.9 billion tons of proven coal reserves – lignite and black coal. Lignite reserves are estimated at 1.85 billion tons and black coal reserves at 47 million tons. The undiscovered coal resources are estimated at 5.7 billion tons. Black coal is located in the Southern regions in Surkhandarya and Kashkadarya. Currently, one lignite deposit is exploited at Angren and two black coal deposits at Shargun and Baysun.<sup>27</sup>

Coal production has been increasing since 2005 due to larger demand by the industrial sector. In 2009, a total of 3.6 million tons of coal was mined, which corresponds to 20 percent increase from 2005. Substantial increase in coal production is expected to be

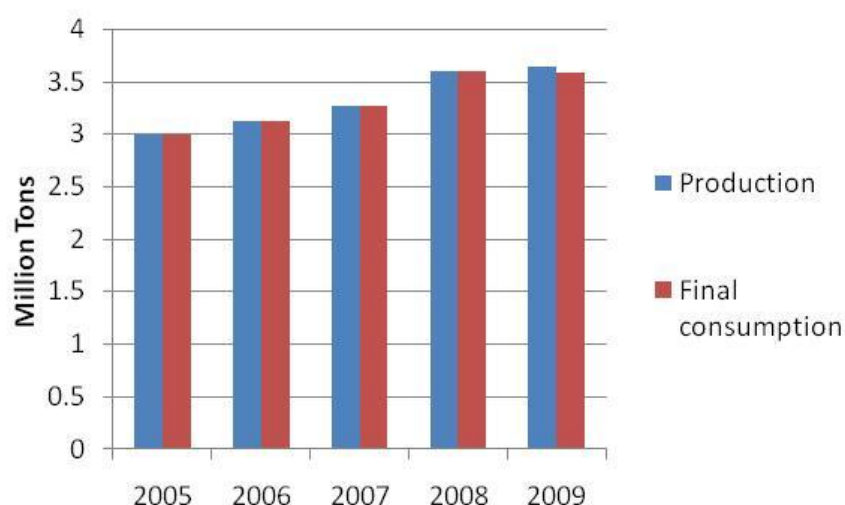
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<sup>26</sup> EIA, Country Analysis Briefs, Uzbekistan, updated January 2012.

<sup>27</sup> Uzbekugol web-site. Accessed on May 10, 2012, [www.uzbekcoal.uz](http://www.uzbekcoal.uz); Uzbekugol Presentation on Prospects of Uzbekistan Coal Sector Development by 2020.

driven by the power sector needs. Figure 1.7 below presents total production and consumption volumes for 2005-2009.<sup>28</sup>

**Figure 1.7: Coal production and consumption**



Source: Industry of Uzbekistan 2009 and 2010, Statistical report, National Statistical Service

Lignite accounts for over 98 percent of coal produced (3.55 million tons) with black coal mining planned to be increased from the current level of 50 thousand tons to 900 thousand tons by 2020.

The energy sector, the residential sector and construction industry are currently the largest consumers of coal accounting respectively for 80, 10 and 6 percent of total consumption. Coal consumption is expected to reach 15 million tons by 2020.

In particular, more coal will be required for electricity generation given the ongoing and planned conversion of gas-fired units to coal-fired at several TPPs. In 2012-2020, the energy sector's share in total consumption is projected to increase from 80 to 90 percent.<sup>29</sup>

Uzbekistan has limited coal exports and prioritizes coal consumption in the domestic market. The Government plans to increasingly replace domestic supply of gas with coal in order to increase gas exports.

The Government mandates wholesale of coal only through commodity exchange of Uzbekistan with exception of coal sales to energy sector enterprises and state budget financed organizations. The wholesale offers are made by the mining companies under

<sup>28</sup> The Governmental Portal of the Republic of Uzbekistan – Energy resources of Uzbekistan. The Government statistics are substantially different from IEA data.

<sup>29</sup> UE web-site. Accessed on May 5, 2012, [http://www.uzbekenergo.uz/eng/coal\\_industry/](http://www.uzbekenergo.uz/eng/coal_industry/); Uzbekugol Presentation on Prospects of Uzbekistan Coal Sector Development by 2020.

Uzbekugol and bids are submitted by wholesale traders. In April-May 2012, the wholesale prices were in the range of UZS 21,100-44,500/ton (US\$11.3-23.4/ton).<sup>30</sup>

### **Infrastructure**

The following four companies are engaged in coal mining: Uzbekugol, Apartak, Shargunkoumir and Erostigaz (the above three owned by Uzbekugol). Uzbekugol has 9 subsidiaries responsible for exploration, mining, operation, repair and maintenance of operational equipment and machinery, operation and maintenance of energy infrastructure, and other operational support.<sup>31</sup>

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<sup>30</sup> Uzbekugol web-site. Accessed on April 5 and May 5, 2012, <http://www.uzbekcoal.uz/products.htm>

<sup>31</sup> Uzbekugol web-site. Accessed on March 25, 2012, <http://www.uzbekcoal.uz/about.htm>

## **2 Overview of the Power Sector**

### **2.1 Structure, Legal and Regulatory Framework**

The majority of Uzbekistan's power generation, transmission and distribution assets are owned and operated by subsidiaries of a single holding company – Uzbekenergo (UE).

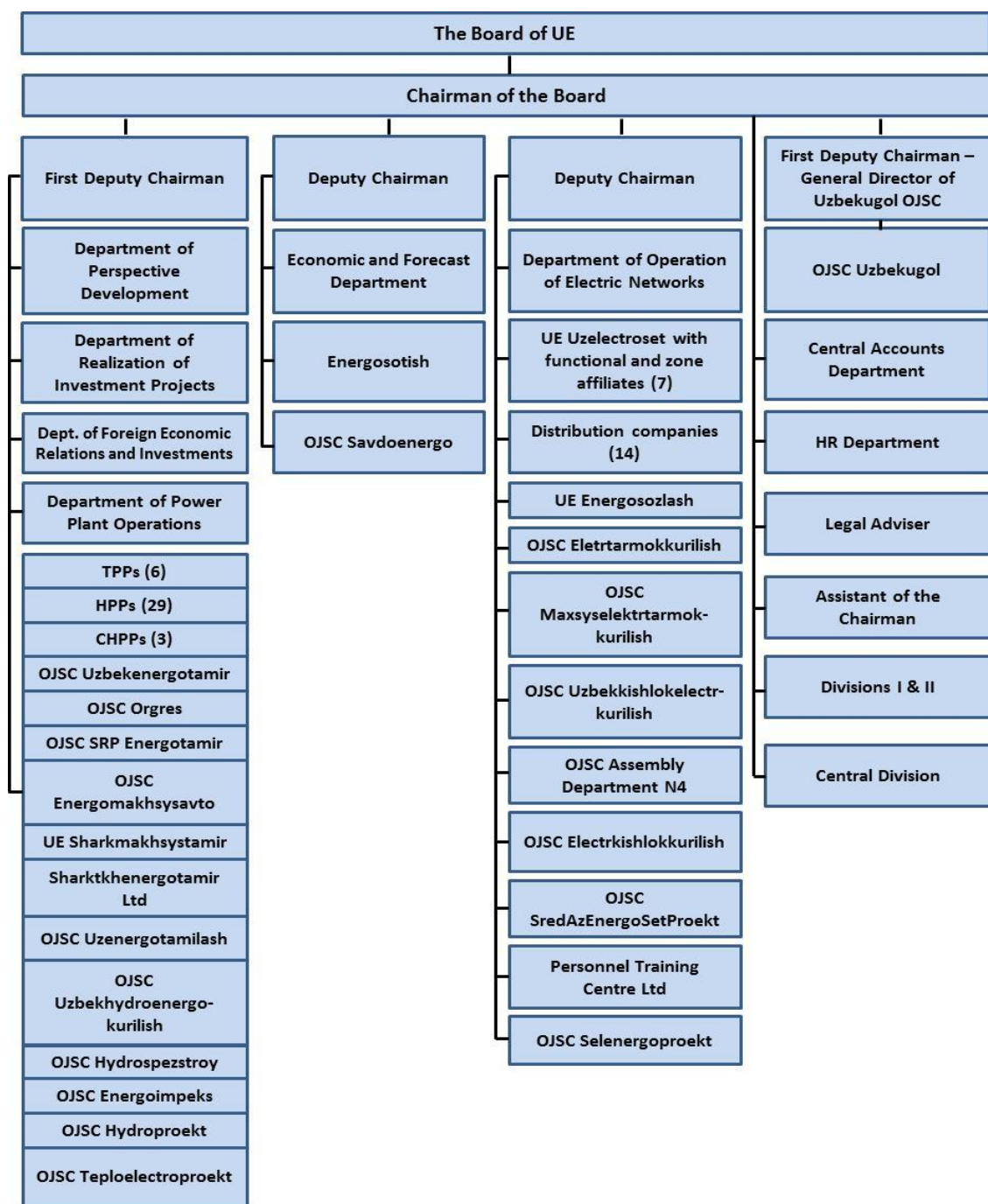
UE is composed of 53 subsidiary companies. As a result of the functional unbundling of the power sector, UE has at least one major subsidiary for each segment: generation, transmission and distribution. UE owns and operates six thermal plants, 29 hydropower plants, and three CHPPs.

Its subsidiary, Energosotish, is the single buyer/the sole wholesale electricity purchaser and supplier. Uzelectroset is the system operator providing dispatch, transmission and network services. Uzelectroset includes seven high-voltage transmission network affiliate operators. Distribution of electricity is done by 14 regional distribution companies. UE electricity sector departments and subsidiaries are shown below in Figure 2.1.<sup>32</sup>

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<sup>32</sup> Uzbekugol is not shown in this figure because it is a coal sector company, not a power sector company.

**Figure 2.1: UE Organizational Structure**

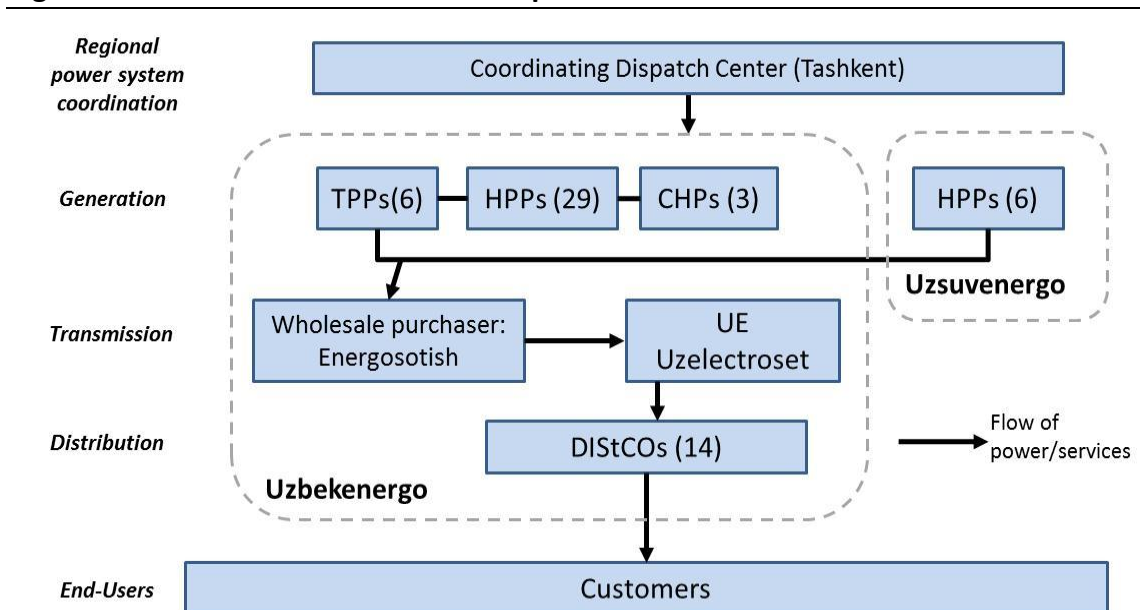


Source: Uzbekenergo.

Figure 2.2 describes the structure of power sector operations in Uzbekistan and the flow of power services to and from each UE subsidiary. Generation companies sell electricity to Energosotish, which sells it to regional distribution companies. Uzelectroset provides transmission services to generators and distribution companies. Large industrial customers are allowed to buy directly from generation companies.



**Figure 2.2: Overview of Power Sector Operations in Uzbekistan**



Source: Bank team.

The Government has initiated a number of important steps to support development of the power sector: (a) secured financing for 50 percent of the critical medium-term investments required by 2015; (b) started a number of important initiatives and projects to further develop and modernize the sector and ensure reliable energy supply, including energy efficiency program aimed at introduction of energy-saving technologies in the economy to improve competitiveness; (c) increased end-user electricity tariffs during 2004-2012, enabling UE to cover operating costs; (d) retained technical experts with skills and experience required for adequate operation and maintenance of assets; and (e) completed the functional unbundling of generation, transmission, distribution, and dispatch. The objective of the reforms was to improve operations and financial viability of the power sector, and to increase the reliability of electricity supply. However, the Government recognizes the need to continue overhauling the legal and regulatory framework to further improve attractiveness of the sector for private investors. The details on key power sector laws and regulations and the roles of the major power sector regulatory agencies are described in Appendix B.

## 2.2 Government Priorities in the Power Sector

The Government recognizes that reliable electricity supply is necessary for sustainable economic growth and development. Therefore, the Government specified the following power sector priorities:

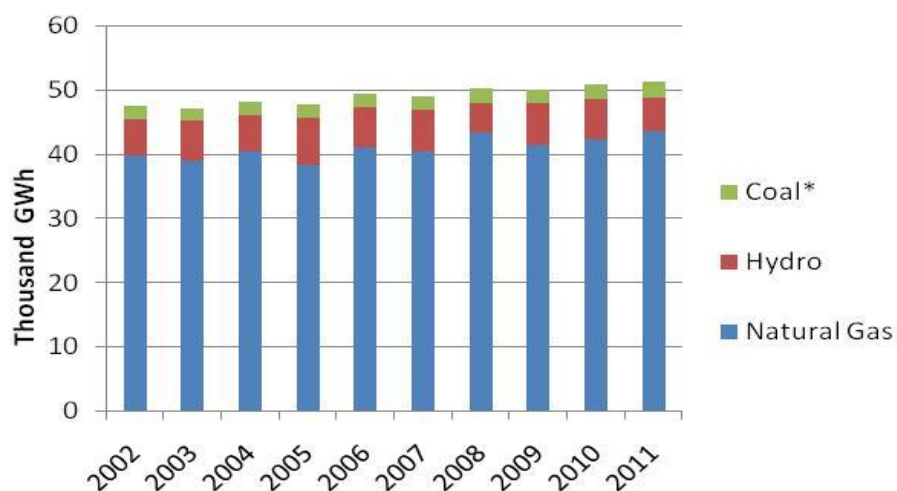
- **Maximizing energy savings** through rehabilitation and modernization of existing power sector assets and introduction of energy-efficiency technologies and equipment in various sectors of the economy to reduce costs and improve competitiveness. The Government also plans to rehabilitate electricity distribution networks and integrate energy efficiency into national planning.

- **Commercializing utility operations to improve performance.** The Government plans to continue de-monopolization and deregulation of the power sector to increase competition. It also prioritizes providing open access to power transmission lines for generation companies.
- **Attracting private sector investments.** Given the large investment needs, the Government plans to rely increasingly on the private sector to finance those investments.
- **Ensuring reliable power supply** given the increased energy demand driven by rapid economic development. This will also include development of the required science as well as research and development foundation for increased penetration of renewable energy.
- **Reducing dependence on gas for electricity generation.** The Government intends to enlarge the share of other supply sources by converting a number of gas-fired thermal plants to coal-fired, constructing new coal-fired power plants and increasing the share of renewable energy.
- **Reducing environmental impact of the power sector.** To that end, the Government plans to increase the share of renewable energy in the power generation mix.

## 2.3 Electricity Supply, Demand and Trade

Uzbekistan's primary fuel for electricity generation is natural gas (82 percent), followed by hydropower (12 percent) and coal (5 percent). Figure 2.3 shows the generation mix over 2002-2011.

**Figure 2.3: Electricity Generation Mix**



Source: Industry of Uzbekistan in 2009 and 2010, Statistical report, National Statistical Service.

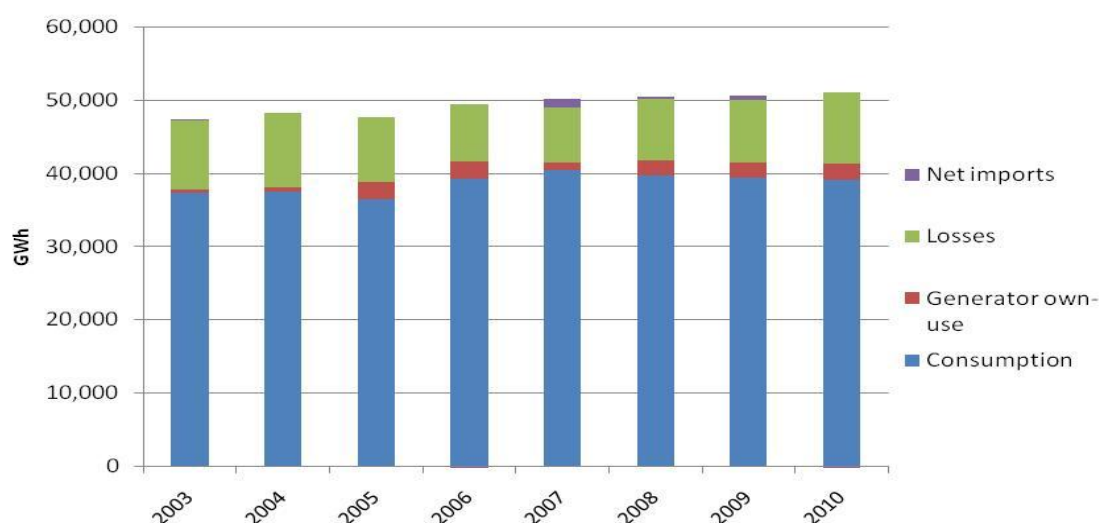
The total installed generation capacity is 12,510 MW. Uzbekistan has 10 thermal generation plants, including three CHPPs,<sup>33</sup> with total installed capacity of 10,660 MW

<sup>33</sup> Which also supply heat to residential and industrial users; see Appendix C for details on heating sector.

and eight hydropower cascades with total installed capacity of 1,850 MW. With the exception of six plants (total capacity 393 MW) that belong to Uzsuvenargo (part of the Ministry of Agriculture and Water Resources), all of these plants are owned by UE. Nearly 40 percent of the total installed generation capacity is past or close to the end of its operating life, and older TPP units operate significantly less efficiently than newer units. Appendix D provides details on HPP and TPP installed capacities and estimated service lives.

As shown in Figure 2.4, total electricity generation grew from 47,200 GWh/year in 2003 to 51,100 GWh/year in 2010. Net imports are typically small, around 1 percent of generation. In 2004, 2005 and 2010 Uzbekistan was a net exporter of electricity.

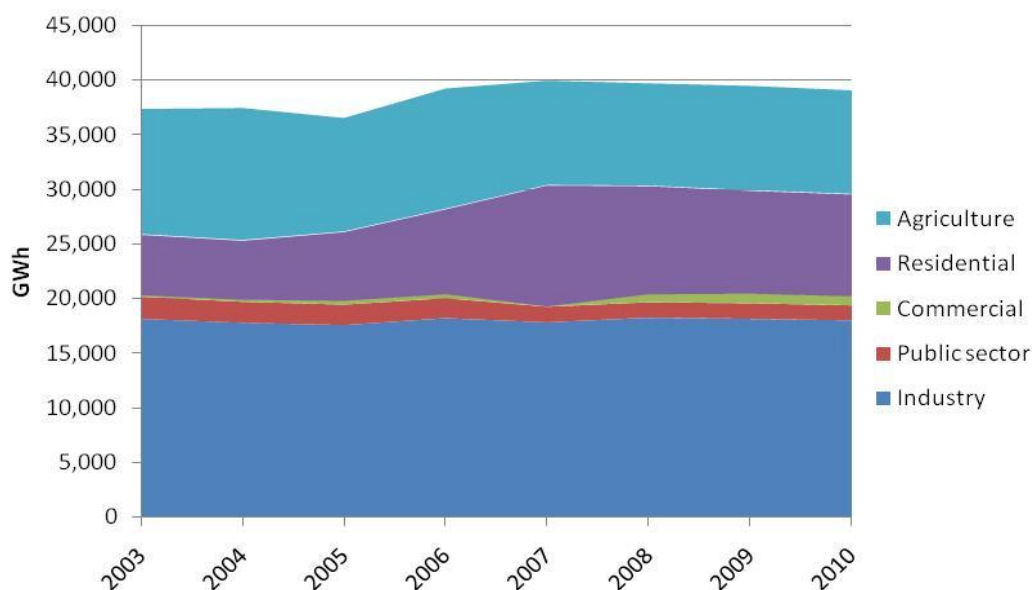
**Figure 2.4: Basic Power Balance**



Source: World Bank team.

Total electricity consumption in 2010 was 39,055 GWh. The industry was the largest consumer of electricity, accounting for more than 45 percent. Residential demand accounted for 24 percent of total consumption, and increased by 70 percent between 2003 and 2010. The increase was driven by expanding household purchases of electric devices/appliances fueled by solid economic growth. Electricity demand in the commercial sector also grew supported by the robust economic growth. Demand in the agricultural sector decreased by 17 percent in 2003-2010, primarily due to reduction of the share of agriculture in GDP and improvements in water pumping efficiency. Figure 2.5 shows the electricity consumption by sectors in 2003-2010.

**Figure 2.5: Structure of Electricity Consumption**



Source: World Bank team.

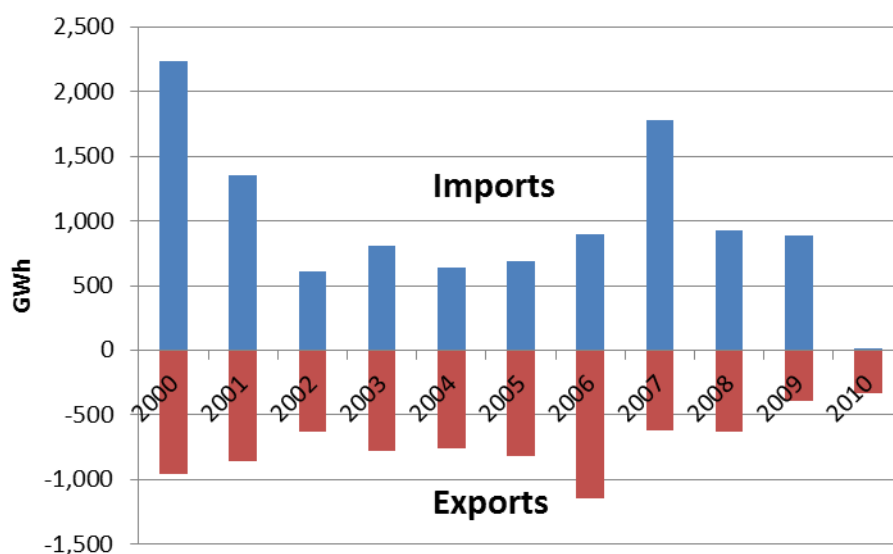
### Electricity trade

Uzbekistan was part of the Central Asia Power System (CAPS), comprised of the interconnected power systems of the five Central Asian countries: Kazakhstan, Kyrgyz Republic, Tajikistan, Turkmenistan and Uzbekistan. The system was built during the Soviet era and designed for regional supply of electricity across the five countries. Despite good interconnection, Uzbekistan's engagement in electricity trade with its neighbors has been decreasing since 2000. Currently, Uzbekistan has only small exports to Afghanistan (1,225 GWh or 2 percent of 2010 generation) and receives some power from the Kyrgyz Republic (600 GWh or 1.2 percent of 2010 generation).

In 2000-2010, Uzbekistan exported on average 577 GWh per year to Tajikistan (1.2 percent of supply)<sup>34</sup> – primarily in winter months when Tajikistan has energy deficits. However, currently there are no exports to Tajikistan. Uzbekistan imported on average 423 GWh (0.9 percent of supply) per year from Kyrgyz Republic and 539 GWh (1.1 percent of supply) per year from Tajikistan during the same period – primarily during summer months, when hydropower-rich neighbors had electricity surplus. Figure 2.6 shows the levels of annual electricity imports and exports, which account for a very small percentage of supply and demand.

<sup>34</sup> Total electricity sent out to the grid.

**Figure 2.6: Energy Imports and Exports Since 2000**



Source: CAREC Power Sector Master Plan, Feb. 2012.

## 2.4 Transmission and Distribution Infrastructure

Uzbekistan has more than 230,000 km of transmission and distribution lines. During 2000-2010, around 1,030 km of new transmission and distribution lines were built. On average, the transmission and distribution lines are approximately 30 years old. Table 2.1 shows the length and average age of transmission and distribution lines at different voltage levels.

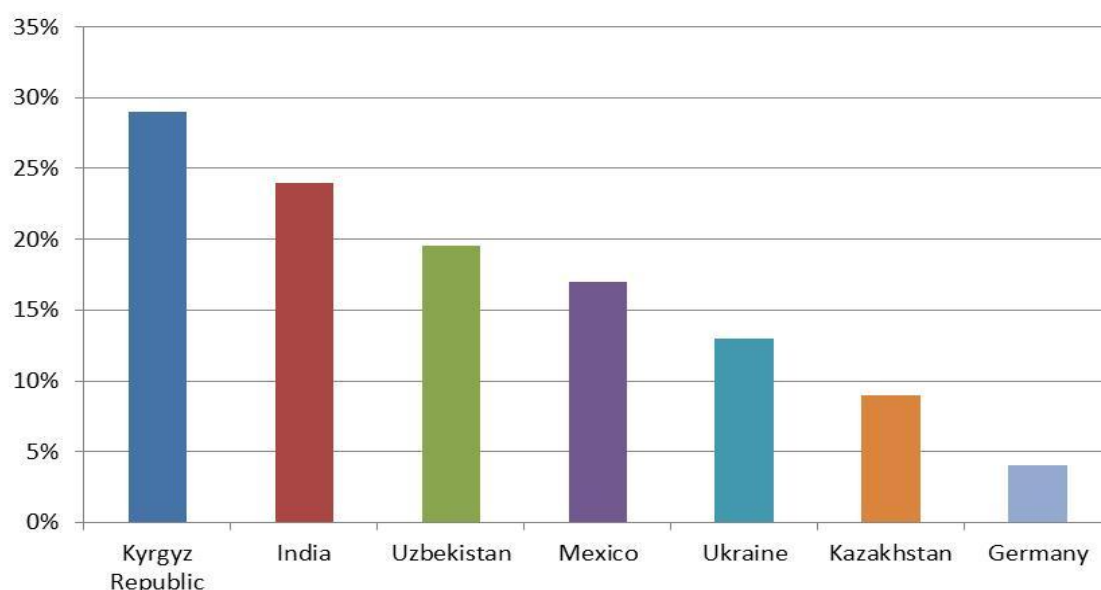
**Table 2.1: Transmission and Distribution Lines by Voltage, Length and Age**

Voltage Level (kV)	Length in 2010 (km)	Average Age (years)
Transmission Lines		
500	2,257	28
220	6,079	30
110	15,300	28
Distribution Lines		
35	13,593	30
6-10	93,983	33
0.4	105,834	*

Source: World Bank team.

Electricity losses in Uzbekistan are relatively high, estimated at 20 percent of net generation. This level is nearly five times higher than losses in Germany. Figure 2.7 shows losses in Uzbekistan compared with its neighbors, other developing and developed countries.

**Figure 2.7: Technical and Commercial Losses Compared with Other Countries (2010), % of net generation**



Source: World Bank team based on WDI and public data from national utilities or energy regulators.

Despite significant investments in line rehabilitation and new line construction, the power grid requires additional investments in order to meet growing demand and improve supply reliability. Additional information on planned investments is provided in Appendix E.

## 2.5 Financial Performance of UE

The overall financial performance of UE is sound and the operating performance and profitability improved in 2010. The liquidity remains adequate due to some improvements in availability of liquid assets (including cash), relieving pressure on the financing of current expenditures and meeting of short-term obligations. Specifically, availability of cash, marketable securities and receivables to meet short-term obligations improved. Nevertheless, the company has significant potential for further improvement of operating efficiency by reducing the receivables estimated at US\$1 billion in 2010 (90 percent of current assets and 100 percent of 2010 revenue). This level of receivables substantially reduces availability of cash given the size of assets tied up. The average collection period of total receivables remains quite high at 295 days – substantially above the collection period of good-performing utilities (30-50 days).

UE initiated a sizeable investment program aimed at expansion and modernization of electricity generation, transmission and distribution assets. Substantial part of that investment program was financed through debt from international financial institutions (IFI) and domestic financial institutions. Therefore, UE reliance on debt increased since 2007. As of 2010, the book value of long-term debt (net of current maturities) was around US\$570 million. The Government plans to increase borrowing for investments, thus, UE's long-term debt is expected to increase further. However, the debt-to-equity ratio is projected to remain within reasonable levels with current plans for borrowings and projected increase in tariffs. The debt-to-equity ratio was

52:48 in 2010. Debt service coverage ratio remains robust and availability of cash for financing of debt service obligations increased. The total book value of the long-term borrowing, including the projects approved in 2009-2011, is projected to reach US\$1.2 billion by the end of 2012 (see Appendix E: for details).<sup>35</sup>

### **Projected Financial Performance of UE**

The long-term financial sustainability of UE will significantly depend on improvements of the operational efficiency (increase in power generation efficiency, reductions in losses) and tariff increases. Increase of operational revenues will be required to ensure timely debt servicing and increase the borrowing capacity against the balance sheet. Tariff increases not commensurate with increases in fuel, salary and O&M expenses of the company will jeopardize financial performance of the company (see Appendix E: for details).

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<sup>35</sup> The loans and credits from IFIs are reflected in UE balance sheet with a lag given the time required for the projects to be ratified and the principal amounts to be on-lent to UE.

### 3 Principal Challenges in the Power Sector

The energy sector faces a number of challenges that need to be addressed to ensure sustainable development of the sector.

The principal challenges are:

1. Supply reliability, especially during winter season;
2. Demand- and supply-side energy inefficiencies;
3. Financing large required investments with minimum impact on state budget;
4. Limited diversification of electricity generation mix with near-complete dependence on gas; and
5. Vulnerability to climate change.

#### 3.1 Supply Reliability

Aging infrastructure and insufficient investments have increasingly resulted in power supply reliability problems in recent years. Sporadic failures of old transmission and distribution infrastructure and transmission capacity bottlenecks contribute to electricity supply disruptions. These problems are especially acute in the southern and western regions. Blackouts are common for 2-6 hours a day in these regions during winter months when load is highest. Rolling blackouts in other regions also occur occasionally during periods of peak demand.<sup>36</sup> Reliability problems appear to have increased throughout the country in 2012. According to some reports, there were rolling blackouts in nearly every part of Uzbekistan during the winter in 2012. In cities, the blackouts occurred for several hours per day and in some remote villages there was no electricity for weeks.<sup>37</sup>

Such problems create economic losses for households and businesses. Specifically, un-served energy in 2010 was estimated at 860 GWh (1.7 percent of total consumption). The country is estimated to have incurred economic loss of US\$52 million<sup>38</sup> during the winter in 2010 because of unreliable supply. The blackouts impose economic and social costs on the society. Some of the consumers replace grid electricity with expensive back-up generation. As an alternative, several consumers use diesel-fired back-up generation, which produce electricity at a cost of roughly US\$0.23/kWh. This is almost four times the average retail electricity tariff in Uzbekistan.

Power shortages were ranked as the third most significant obstacle for doing business according to the Doing Business Report (2009). An EBRD-World Bank Survey (2010) found that dissatisfaction with quality of electricity service was higher in Uzbekistan

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<sup>36</sup> World Bank, Climate Vulnerability, Risk and Adaptation Assessments. Helping Countries Prepare an Effective Power Sector Response: Focus on Uzbekistan Draft Final Report, June 2012.

<sup>37</sup> Tashpulat Yuldashev, Uzbekistan's power crisis - why is there no heat and light?, *UZNews.net*, Jan. 18 2012. Accessed April 11, 2012, [http://www.uznews.net/news\\_single.php?nid=18788](http://www.uznews.net/news_single.php?nid=18788)

<sup>38</sup> Calculated by the Bank team assuming cost of un-served energy at US\$0.06/kWh. Estimated using willingness-to-pay approach assuming un-served electricity demand is entirely eliminated by 2020 and average price elasticity of demand at minus 0.2 (no data available on un-met demand by categories of consumers).



than in other CIS countries. More than one-third responded that they were highly dissatisfied with electricity supply services in the country.<sup>39</sup>

### **3.2 Demand- and Supply-side Energy Inefficiencies**

Uzbekistan is the second most energy-intensive economy in the world as measured by energy intensity per unit of GDP.<sup>40</sup> Uzbekistan uses two times more energy than Kazakhstan and nearly three times as much as the ECA average to produce a unit of GDP.

Uzbekistan has high level of energy intensity at all links of the energy sector value chain. The main sources of energy inefficiencies are gas flaring, low efficiency of TPPs, transmission and distribution losses and low energy efficiency on demand side.

Low energy efficiency is both a short- and long-term challenge. It is an immediate and pervasive problem, which is inherent to all end-users of electricity, and will persist if the following key obstacles are not eliminated: (a) lack of incentives to improve efficiency; (b) large investment needs and barriers to access financing for energy efficiency investments; (c) limited number of private companies involved in provision of energy efficiency services and manufacturing of energy efficient goods; (d) lack of capacity in commercial and industrial sector to assess the potential and viability of energy efficiency investments; (e) limited knowledge and awareness among end-users about the benefits of energy efficiency investments; and (f) underdeveloped legal, regulatory, policy and institutional framework for energy efficiency.

The following subsections describe the potential for improvements in energy efficiency at supply and demand side, focusing primarily on the power sector.

#### **Supply-side Energy Efficiency**

The potential to improve efficiency of electricity generation plants, reduce losses in transmission and distribution, and reduce gas flared in oil and gas production is significant.

##### ***Electricity Generation***

The old steam-cycle, natural gas-fired TPPs have low thermal efficiencies compared to modern combined-cycle gas turbine plants (CCGTs). The weighted average thermal efficiency of gas-fired thermal generation fleet is 33 percent, and some plants have efficiencies as low as 23 percent. Due to modern technology and use of two-cycle energy recovery, newer CCGTs have thermal efficiencies of 53-56 percent. In 2010, the country could have saved US\$1.2 billion worth of gas (2.6 percent of GDP)<sup>41</sup> by using gas-fired plants with higher efficiency. Alternatively, improved generation efficiency would allow the country to produce additional 24,000 GWh of electricity (50 percent of total 2011 generation), which could help to meet the looming demand-supply gap.

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<sup>39</sup> EBRD- World Bank Life in Transition Survey 2006 and 2010.

<sup>40</sup> Enerdata, Energy intensity of GDP at constant purchasing power parities, *Yearbook Statistical Energy Review 2010*. Accessed April 26, 2012, <http://yearbook.enerdata.net/2009/energy-intensity-GDP-by-region.html>

<sup>41</sup> At US\$250/tcm export price.

Appendix D contains additional information on the efficiencies of the current TPP fleet.

### ***Transmission and Distribution***

Transmission and distribution system losses are estimated at 20 percent of net generation. These levels are 2-4 times higher than commercial and technical losses in high and some middle income countries. Uzbekistan can reduce the electricity losses by upgrading and rehabilitating infrastructure as well as changing metering and billing practices. The annual cost of excess electricity losses is estimated at US\$340 million (0.8 percent of GDP).

Technical losses account for 13.7 percent of net generation. Most of the losses occur on the low voltage transmission (110 kV) and distribution system at 0.4 to 35 kV. Technical losses are caused by overloading of T&D lines and other infrastructure. Reducing technical losses from the current level of 13.7 percent to 9 percent of net generation would save the country US\$6 billion (0.4 percent of cumulative GDP) over a 20-year period.<sup>42</sup>

Commercial losses account for 5.8 percent of net generation. Commercial losses are caused by inaccurate meter reading technology and reporting inaccuracies. The majority of existing meters is beyond their service lives and has not been recalibrated to ensure accuracy. Commercial losses also have a significant economic impact. Reducing commercial losses from 5.8 percent to 3 percent would save US\$1.2 billion (0.1 percent of cumulative GDP) over a 20-year period.<sup>43</sup>

### ***Gas Flaring***

Uzbekistan is one of the top 20 gas flaring countries in the world.<sup>44</sup> Gas flaring wastes valuable natural gas resources and contributes to climate change. Since 1994, gas flaring has increased at an annual average rate of four percent, reaching 1.8 bcm in 2010 - a volume equal to 3 percent of natural gas production in 2010 or annual consumption of Armenia. The flared gas was worth roughly US\$500 million in foregone export revenues (1.1 percent of GDP).

### ***Demand-side Energy Efficiency***

Uzbekistan's industry and agriculture are the most energy intensive and are estimated to have the largest potential for savings.

#### ***Low Energy Efficiency of Industry***

Industry is the single largest consumer of electricity and also one of the largest sources of energy inefficiency. The most energy intensive industries in Uzbekistan include metallurgy, construction material manufacturing (brick and cement), chemical industry, and mining. These industries use outdated and energy-inefficient technology, and several of the industrial enterprises reportedly are not aware of energy efficient technologies and the potential benefits from investing in those

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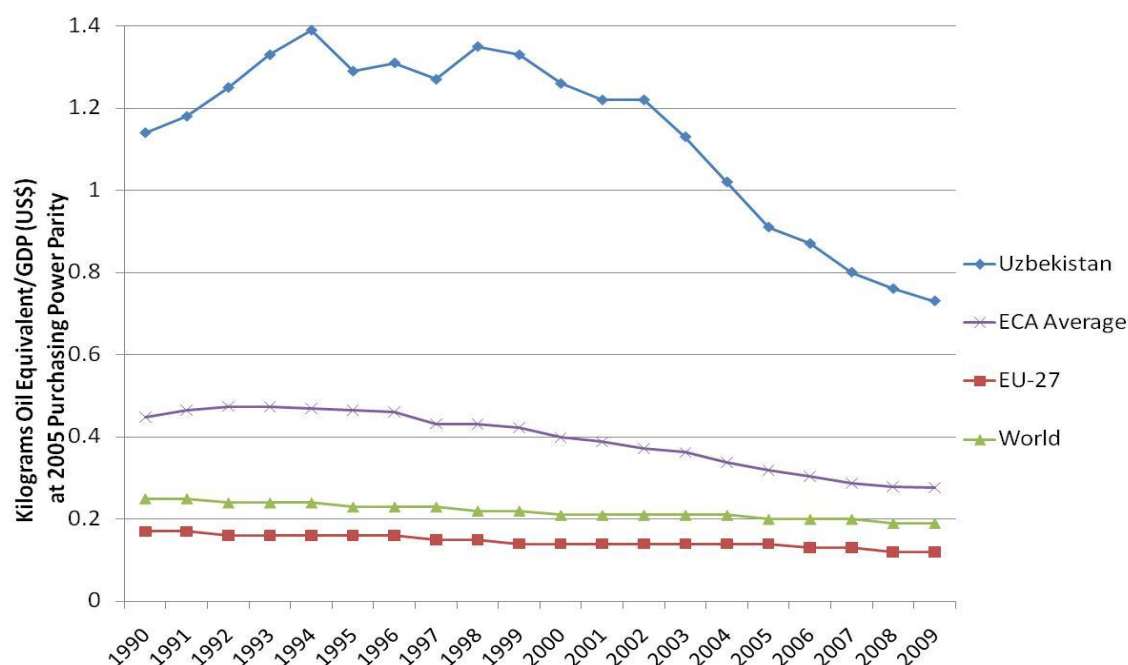
<sup>42</sup> Bank team estimate.

<sup>43</sup> Bank team estimate.

<sup>44</sup> Global Gas Flaring Reduction, "Estimated Flared Volumes from Satellite Data, 2006-2010," March 23, 2011. Accessed April 19, 2012, <http://go.worldbank.org/G2OAW2DKZ0>.

technologies. As a result, Uzbekistan's energy use per unit of GDP is 2.6 times higher than the ECA average of 0.28 and more 6 times higher than the EU-27 average of 0.12 kgoe/GDP.

**Figure 3.1: Energy Intensity (kgoe/GDP)**



Source: Stuggins, Garry; Sharabaroff, Alexander; Semikolenova, Yadviga, "Lessons Learned From Energy Efficiency Success Cases," The World Bank, 2012.

The short-term energy efficiency potential in industrial sector, based on compiled survey results under the EE Strategy for Industrial Enterprises (2012), is estimated at 25-30 percent, while bigger potential could be tapped in the long-term if more enabling environment for energy efficiency is created.

### **Low Energy Efficiency of Agriculture**

Agriculture is also one of the most energy intensive sectors of the economy. This is due to the sector's heavy reliance on pumped water for irrigation and inefficient water pumping infrastructure.

The country requires significant water pumping in order to irrigate farmland. Around 74 percent of the electricity used by the agricultural sector is used to operate irrigation pumps. Additionally, more than 65 percent of the pumping stations have exceeded their useful service life and are in need of replacement or rehabilitation. Inefficient use of water for irrigation also adds to the energy demand. The Government has already started a program to modernize pumping stations and plans to invest US\$14 million in modernization of pump stations in 2012-2014.<sup>45</sup>

<sup>45</sup> World Bank, Climate Vulnerability, Risk and Adaptation Assessments. Helping Countries Prepare an Effective Power Sector Response: Focus on Uzbekistan Draft Final Report, June 2012

### **3.3 Financing Large Required Investments with Minimum Impact on State Budget**

Uzbekistan needs at least US\$33.7 billion of new investment in the energy sector by 2015 to meet increasing demand and to replace/rehabilitate ageing and inefficient assets.

The Government estimates that US\$28.5 billion will be required to finance capital expenditure in the oil and gas sector by 2015. The Government managed to attract sizeable foreign investments, which, coupled with UNG own resources, helped to finance most of the priority gas and oil projects. The Government plans to further rely on UNG own resources and increasingly attract foreign investments to finance exploration and production to meet increasing domestic and export demand.

In the power sector, the Government has yet to utilize the potential for attracting funds for the required investments. Total financing required for the power sector by 2020 is estimated at US\$8.4 billion.<sup>46</sup> The investments are required for replacement of ageing and inefficient electricity generation plants as well as rehabilitation and replacement of electricity transmission and distribution assets to improve supply reliability and meet increasing demand. UE has secured 42 percent of the required investments (US\$3.5 billion). From US\$3.5 billion of projects with secured financing, US\$2 billion worth of projects are under implementation. However, the sector is estimated to require additional US\$4.9 billion by 2020. Appendix F: summarizes the investments planned in Uzbekistan's energy sector, and the status of financing. Without those investments, reliability of supply will be further jeopardized, and as described above, there are signs of strain already.

Power sector investments have historically been publicly funded. Predominantly public financing of power sector investments will not be feasible going forward and is not a sustainable economic strategy. The Government will need to explore other options, including ways to increase the sector's capacity to generate more cash internally and attract private investors.

The Government will need to further increase tariffs to gradually converge to long-run supply costs<sup>47</sup> in order to increase self-financing of UE and attract private investments. The Government increased tariffs by an average annual nominal rate of 12 percent in 2004-2011, which enabled UE to cover its operating costs. Currently, the power sector pays US\$62/tcm, which is lower than the export price, but estimated to be above the short-run supply cost for natural gas, thus, there are no financial subsidies in the sector.

However, current average tariff of US\$0.054/kWh is not high enough to enable UE to finance US\$5 billion of required investments until 2020 with unsecured financing. In 2006-2011, UE self-financed around US\$400 million of projects and increased long-

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<sup>46</sup> Based on CAREC Power Sector Master Plan, ADB, Feb. 2012 and Bank team estimates.

<sup>47</sup> The long-run marginal cost of supply was estimated at US\$0.11/kWh.

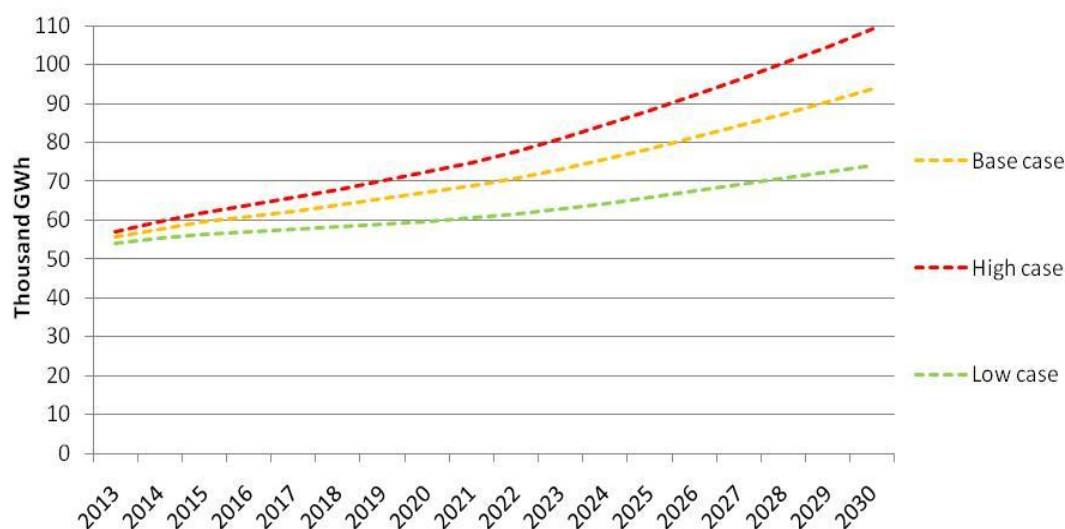
term debt to US\$1.2 billion (primarily power sector projects financed by IFIs and other donors), which will limit borrowing capacity without increase in revenues.

### ***Meeting increasing demand***

Electricity demand and peak load growth are forecasted to be driven primarily by increase in industrial and residential demand. Industrial demand is expected to grow as the Government promotes industry and export-led growth as pursued under Uzbekistan Development Vision 2030. Residential demand is expected to increase as economic growth raises disposable income of households and, thus, increases demand for new electric household equipment and appliances.

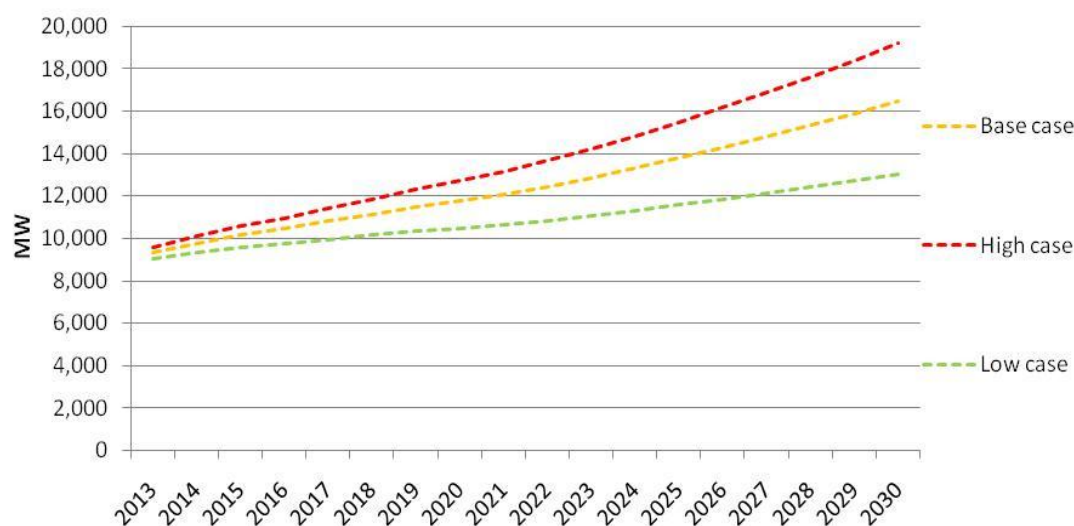
Peak load is also expected to grow, but at a faster rate than consumption. Figure 3.2 shows electricity consumption growth scenarios and Figure 3.3 shows peak load growth scenarios. For the analyses in this report, the “Base Case” electricity consumption and peak load forecasts are used. For more details, please see Appendix G:.

**Figure 3.2: Electricity Consumption Forecasts**



Sources: Bank team estimate.

**Figure 3.3: Peak Load Forecasts**



Sources: Bank team estimate.

### ***Replacing old infrastructure***

Most of Uzbekistan's electricity generation fleet is past or near the end of its useful service life. Specifically, 20 percent of existing generation capacity is past the useful service life, which will increase to 40 percent by 2017. Most of the existing generation plants are in urgent need of rehabilitation or replacement.<sup>48</sup>

Much of Uzbekistan's electricity transmission and distribution assets are also approaching the end of their service lives. Sixty percent of 500 kV lines and 50 percent of 500 and 220 kV substations are within 10 years of the end of their service lives. Moreover, expansion of the transmission system has not kept pace with growth in electricity demand in recent years. As a result, the transmission system is consistently overloaded, leading to high technical losses and prolonged blackouts.

The Government estimated that US\$1.3 billion will be required for investments (US\$630 million secured) in transmission and distribution systems by 2020. This includes projects aimed at developing, rehabilitating, and modernizing transmission lines, substations, switchyards and new distribution-level infrastructure, such as advanced electrical meters for individual customers.

### ***The demand-supply gap***

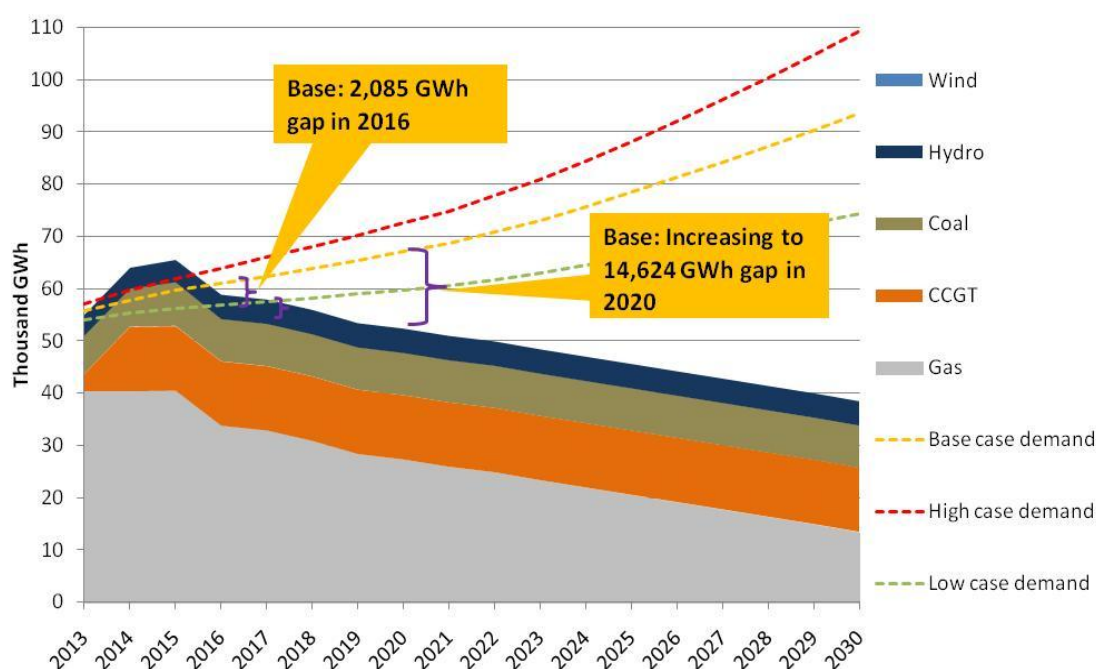
The country is estimated to require US\$7.1 billion of generation investments by 2020. Some new generating capacity is planned to come online by 2015 (US\$2.8 billion worth of projects), and the Government is seeking US\$1.1 billion of financing for rehabilitation of some generation assets (primarily HPPs). However, at least additional US\$3.2 billion will be required for investments in new generation capacity to ensure

<sup>48</sup> CAREC Power Sector Master Plan, ADB, Feb. 2012.

adequate electricity supply.<sup>49</sup> Under the base-case demand scenario, electricity supply gap of 2,085 GWh (3.5 percent of demand) and supply capacity gap of 605 MW is expected to emerge in 2016. Under the base-case scenario, the electricity supply shortage is estimated to reach 14,624 GWh (20 percent of demand) and the supply capacity gap to each 3,383 MW by 2020 if the required investments are not made and the Government discontinues existing old and inefficient gas-fired units.<sup>50</sup>

Figure 3.4 below shows the forecast electricity supply-demand gap and Figure 3.5 shows the forecast gap between generation capacity and supply required to meet peak load plus reserve margin.<sup>51</sup>

**Figure 3.4: Forecast Generation-Consumption Supply Gap under Base-Case Scenario**



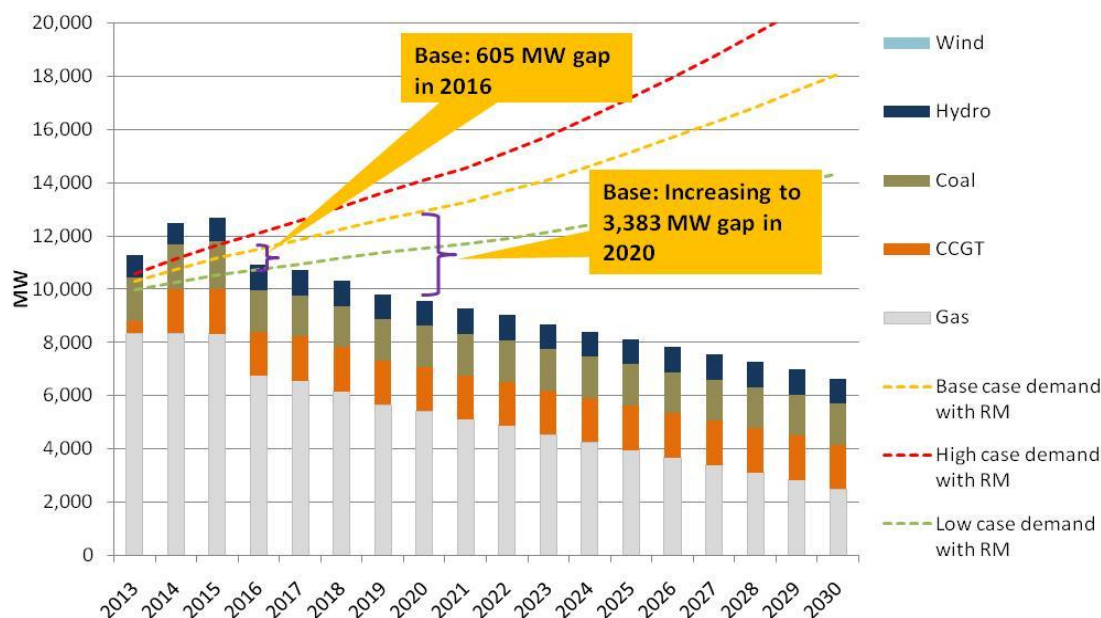
Source: Bank team estimate.

<sup>49</sup> Assuming the incremental demand is met with new gas-fired plants.

<sup>50</sup> Assuming some of the TPPs that are due to retire this or next years will be extended for 3 years. For the purposes of the analysis, all TPPs are assumed to have useful service life of 50 years and HPPs are operated throughout the planning horizon as the Government plans to invest over US\$1 billion in rehabilitation of all hydropower plants.

<sup>51</sup> The analysis assumes a 20 percent reserve margin is required above annual peak demand.

**Figure 3.5: Forecast Capacity-Peak Load Supply Gap under Base-case Scenario (with Reserve Margin)**



Source: Bank team estimate.

Note: A 20% reserve margin is assumed. It is assumed that half of this reserve to be provided by plants that have reached the end of their useful lives but will still be serviceable to meet peaks.

The investment requirements will very much depend on the electricity supply mix diversification the Government would pursue and might be substantially higher. The Government has already started diversifying the electricity supply mix by converting some gas-fired generation units into coal-fired and committing to wind and solar projects, however, those efforts need to be sustained into future.

### 3.4 Limited Diversification of Electricity Generation Mix with Near-complete Dependence on Gas

As described in Section 2, Uzbekistan is highly dependent on natural gas for electricity generation. The high dependence on natural gas poses three problems:

- **Foregone revenue from gas exports.** Each cubic meter of gas used to generate electricity is a cubic meter that cannot be exported. Therefore, using natural gas to generate electricity has an opportunity cost for Uzbekistan equal to the export price.
- **Suboptimal load management.** Excessive reliance on gas-fired electricity generation complicates load management. Specifically, most of the existing gas-fired plants are designed as baseload generation and their efficiency reduces when operated for meeting the peak load.
- **Higher vulnerability to climate change.** In the long-term, the changing climate patterns in Uzbekistan might diminish availability of water for TPPs and impact their efficiency.



In order to address those challenges, Uzbekistan should explore other supply options, including coal, renewables, and trade with other countries.

### Coal

Currently, the share of coal in electricity generation mix is 3 percent, but the Government intends to increase the share of coal-based electricity generation. Therefore, it is currently converting a number of generation units from gas- to coal-fired and plans to convert additional units in the next few years.

### Renewables

Uzbekistan has significant renewable energy resource potential, including hydropower, solar, and wind. Some estimates of the technical potential of renewable energy resources have been made (see Table 3.1), but no comprehensive assessment of the economically and financially viable renewable energy potential has been done so far.

**Table 3.1: Estimated Technical Potential for Renewable Energy Resources (Electricity Production)**

Resource	Technical Potential	Utilized Potential
	GWh/year	GWh/year
Solar energy	2,058,000	0
Large and medium hydropower	20,934	1,650
Small hydropower	5,931	200
Wind	4,652	0
Biomass	1,496	0
<b>Total 2011 electricity generation</b>	<b>50,000</b>	

Source: The Outlook for Development of Renewable Energy in Uzbekistan, UNDP, 2007; Bahtiyor R. Eshchanov et al., Potential of Renewable Energy Sources in Uzbekistan, *Journal of Knowledge Management, Economics and Information Technology* 7 (December 2011): 3-14; CAREC Power Sector Master Plan, ADB, Feb. 2012; Bank team

### Electricity Trade

The power systems of Uzbekistan and its neighboring countries became increasingly isolated. Turkmenistan disconnected from CAPS in 2003 and Tajikistan disconnected in 2010. Their power systems now operate in isolation and Uzbekistan has limited electricity trade within CAPS. Missed energy trade opportunities result in foregone electricity and gas export revenues as well as provision of efficient and least cost electricity supply to consumers. Limited trade may also result in less efficient system operation and reliability, which can be improved with greater diversity of electricity supply.

Most of Uzbekistan's thermal plants were designed for base-load generation in the regional system, but are currently being used for inter-hour power generation regulation or "load-following." Using these plants in such a way reduces their thermal efficiency. It can also cause outages and other reliability problems, because base-load thermal plants cannot be ramped up and down quickly to respond to rapid changes in demand. Additionally, the country could have imported lower cost electricity during

summer months from hydro-rich neighboring countries, which spill water due to limited export opportunities.

### 3.5 Vulnerability to Climate Change

Changes in hydrology, air temperature and extreme events are likely to affect energy security in the long term, with expected measurable impacts on energy supply in 2030.

Climate change impacts on the energy sector might materialize across the whole value chain and are likely to create additional costs for the sector if no mitigation and adaptation measures are put in place. In particular, climate change might affect the power sector through:

- **Reduction in electricity generation.** Electricity generation will be affected primarily through:
  - **Reduced generation by TPPs.** Climate change is expected to affect operation of TPPs through negative impacts of droughts and floods on the system reliability. Droughts may cause temporary unavailability of cooling water, while floods could overwhelm the cooling systems of these plants. Increased air temperatures are estimated to reduce generation of direct steam single-cycle TPPs by as much as 1 percent by 2030 and those of CCGTs by 0.5-0.9 percent.

Reductions in average river flows after 2030 are expected to result in shortages of cooling water for TPPs, which will reduce their efficiency and potentially affect their reliability. Water shortages in the summer are already reported to affect the Syrdarya TPP.
  - **Variable generation by HPPs.** HPP generation might be affected by: (a) increased spring/summer runoff in some river basins by 2030 and (b) reduced runoff thereafter. In particular, rising temperatures will cause higher rates of snow-melt at glaciers feeding Amudarya and Syrdarya rivers and, thus, cause increased runoff. This might cause spill-over at HPPs and threaten dam security. Generation might reduce also due to increased rates of reservoir sedimentation caused by heavy rainfall and soil erosion. Forecast reduction in river runoff after 2030 will reduce availability of water for electricity generation.
- **Reduction in efficiency of electricity transmission and distribution.** Rising temperatures will impact the efficiency of electricity transmission and distribution by reducing ability of lines and other equipment to lose heat to the environment. Additionally, increased precipitation may increase the incidence of landslides and mudflows damaging transmission and distribution infrastructure (e.g. transmission pylons, substations).<sup>52</sup>
- **Increase in electricity demand and changes in consumption patterns.** Cooling loads in the residential, commercial and industrial sectors are expected to increase as the climate warms, which will drive increases in electricity consumption.

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<sup>52</sup> Climate Vulnerability, Risk and Adaptation Assessments. Helping Countries Prepare an Effective Power Sector Response: Focus on Uzbekistan. Draft Final Report, World Bank, June 2012.

However, heating requirements in winter months are expected to decrease due to rising temperatures. Overall, reductions in heating loads are expected to have a lower effect on electricity demand growth than increases in cooling loads in the winter. Increasing temperatures will cause higher demand for electricity in the agricultural sector. Rates of evaporation in irrigation systems will be higher, requiring more water to irrigate crops and the amount of energy needed for water pumping.<sup>53</sup>

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<sup>53</sup> Climate Vulnerability, Risk and Adaptation Assessments. Helping Countries Prepare an Effective Power Sector Response: Focus on Uzbekistan. Draft Final Report, World Bank, June 2012.

## 4 Potential Solutions to the Challenges

Table 4.1 summarized a set of immediate actions the Government can start implementing to meet the challenges described in Section 3.

**Table 4.1: Solutions to Challenges**

Challenges	Immediate actions to address the challenges
1. Supply reliability, especially during winter season	<ul style="list-style-type: none"> <li>▪ Prioritize T&amp;D infrastructure to eliminate bottlenecks and reduce losses</li> <li>▪ Use opportunities for regional trade to reduce supply shortages</li> <li>▪ Accelerate improvement of demand- and supply-side energy efficiency</li> </ul>
2. Demand- and supply-side energy inefficiencies	<ul style="list-style-type: none"> <li>▪ Bolster agricultural and industrial energy efficiency</li> <li>▪ Scale up efforts targeting energy efficiency improvements in residential and public sectors</li> <li>▪ Invest in more efficient fossil-fuel based generation considering diversification needs</li> <li>▪ Continue T&amp;D loss reduction programs</li> <li>▪ Assess technical and economic viability of various options for capture and utilization of flared gas</li> </ul>
3. Financing large required investments with minimum impact on state budget	<ul style="list-style-type: none"> <li>▪ Pursue contract-based Independent Power Producer (IPP) projects to attract private capital without major changes to existing structural and institutional arrangements of the sector</li> <li>▪ Improve prioritization of investments based on sound cost-benefit analyses</li> <li>▪ Explore options to increase UE revenues through efficiency improvements and additional tariff increases to enhance the borrowing capacity</li> </ul>
4. Limited diversification of electricity generation mix with near-complete dependence on gas	<ul style="list-style-type: none"> <li>▪ Conduct sound generation options study to plan for diversification of generation mix to utilize renewable energy (e.g. small hydro, solar, wind) and coal resources</li> <li>▪ Carefully analyze tradeoffs when converting the existing gas-fired plants to coal <ul style="list-style-type: none"> <li>- New coal-fired plants are 20 percent more efficient than those converted from gas-fired</li> <li>- Coal-fired plants are more efficient and reliable when run as base-load</li> <li>- Construction of new coal-fired CHPPs close to industrial centers with heat demand can ensure higher efficiency</li> </ul> </li> </ul>

Challenges	Immediate actions to address the challenges
	<ul style="list-style-type: none"> <li>of generation</li> <li>- Technical and economic viability of carbon capture from coal plants and sequestration to enhance oil and gas recovery at existing fields</li> <li>▪ Use opportunities for electricity imports</li> </ul>
5. Vulnerability to climate change	<ul style="list-style-type: none"> <li>▪ Diversify the electricity generation mix</li> <li>▪ Continue improving energy efficiency</li> <li>▪ Improve management of water resources</li> <li>▪ Strengthen facility and disaster risk management</li> <li>▪ Improve knowledge and strengthen the key responsible institutions</li> </ul>

The following sections describe each of the above solutions in more detail.

#### **4.1 Prioritize T&D Infrastructure and Increase Regional Trade**

Supply reliability can be enhanced by investing in improvements of transmission and distribution networks, through more extensive seasonal trade with neighbors, and improvements of demand-side energy efficiency (see Section 4.2).

##### **Improve T&D Infrastructure to Eliminate Bottlenecks and Reduce Losses**

Investments in transmission networks will help to reduce congestion and overloading, improve supply reliability, especially during peak times of winter, and reduce electricity losses. The benefits of loss reduction through metering and distribution network improvements are larger per unit of expenses, compared to similar transmission investments, and also help to improve the supply reliability.

The Government has already undertaken steps to improve reliability of transmission and distribution networks. Specifically, UE has been investing in the transmission system since 2000, gradually adding and rehabilitating transmission lines and substations between major power plants and load centers. The new transmission infrastructure serving the Talimarjan TPP is expected to improve electricity service in the South-Western region of the country and reduce losses due to congestion of existing lines.<sup>54</sup> The Government is also implementing an advanced metering project, which will enable UE to: (a) improve fault detection, contributing to improved quality of service; (b) reduce commercial losses; and (c) implement demand side management (DSM) programs, which will help to improve energy efficiency.<sup>55</sup>

However, significant additional upgrades and additions to the existing and aged transmission and distribution networks are necessary. Roughly US\$1.3 billion in

<sup>54</sup> World Bank, Project Appraisal Document on a Proposed Loan in the Amount of US\$110 Million to the Republic of Uzbekistan for the Talimarjan Transmission Project, February 3, 2011, pp. 19-20

<sup>55</sup> Asian Development Bank, "Economic and Financial Analysis," p.1

investments are needed in the transmission and distribution system by 2020 for development and rehabilitation/modernization of transmission lines, substations, switchyards and new distribution-level infrastructure such as advanced electrical meters for individual customers. Some of the required financing has already been secured: US\$630 million has been committed from a mix of UE own funds, IFIs and bilateral cooperation. However, additional US\$670 million is required in order to implement the remaining rehabilitations, upgrades and new projects.<sup>56</sup>

The Government may consider implementing a detailed study to identify critical transmission network bottlenecks and derive detailed investment cost estimates. We recommend prioritizing investments in modernization of distribution networks to improve power supply reliability and reduce losses. The Government should consider optimizing and standardizing the distribution voltages, using high voltage distribution system, such as the practice in North America and other countries using low-loss small distribution transformers.

### **Use Opportunities for Regional Trade**

Greater seasonal and daily electricity trade within CAPS would allow Uzbekistan to supplement investments in new assets to improve reliability and lower the overall cost of electricity supply. In particular, Uzbekistan could back down some of its gas-fired plants in spring and summer, and import electricity from hydro-rich neighbors. The latter have large hydropower systems with substantial electricity surplus during spring and summer and deficits during winters. Uzbekistan could also improve load management through daily trade during winter season by supplying electricity to the above countries during off-peak hours and importing during peak hours to help meet part of its peak demand. The large storage hydropower plants in those countries are well suited for following daily fluctuations in load. Uzbekistan's gas plants are well suited to provide base-load power to the region.

Increased seasonal power trade within CAPS is economically beneficial for Uzbekistan. Uzbekistan could save at least US\$60-70 million/year if during summer months it imports an average of 1,400 GWh from hydro-rich neighbors<sup>57</sup> with import tariffs of around US\$0.035/kWh, which is 60 percent lower than the thermal generation costs for Uzbekistan.<sup>58</sup>

More efficient use of regional resources would reduce the need for new generation capacity. Coordinated and optimized seasonal power trade with hydro-rich neighbors could avoid the need for the construction of 500 MW of generation capacity in Uzbekistan. This would save an investment cost of around US\$700 million, assuming CCGTs were built.

The Government also wants to expand exports to South Asian countries. In the longer term, the opportunities for competitive exports are limited; however, the Government

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<sup>56</sup> CAREC Power Sector Master Plan, Feb. 2012, pp. 10-2-4-1 to 10-2-4-3.

<sup>57</sup> The highest actual imports observed in 2006-2010.

<sup>58</sup> World Bank team calculation, assuming 100 summer days, import tariff from Kyrgyz Republic and Tajikistan at US\$0.035/kWh, and LRMC for Uzbekistan at US\$0.11/kWh.

can capitalize on short-term trade opportunities. In particular, Uzbekistan has some short-term opportunities for electricity exports to Afghanistan and Pakistan, which have growing demands and lagging domestic generation capacity. Pakistan's peak demand is forecasted to more than double in 2012-2023, increasing from 23,491 MW to 48,885 MW. Uzbekistan can and currently does offer electricity at prices below the estimated long-run supply costs in Pakistan and Afghanistan. In 2010, Uzbekistan exported 150 MW to Afghanistan at a price of US\$0.06/kWh. Uzbekistan currently does not export electricity to Pakistan.

However, even with construction of new efficient generation capacity (e.g. CCGTs or efficient coal-fired generation) Uzbekistan is unlikely to be a competitive exporter of electricity to Pakistan and Afghanistan (except for limited opportunities to supply electricity to meet daily peaks in those countries) in the long-term given the low-cost electricity available from existing (in some cases fully depreciated) HPPs of hydro-rich neighbors<sup>59</sup> and potential competition from Turkmenistan with abundant gas reserves.

## **4.2 Expand Demand-side Interventions and Invest in Supply-side Efficiency**

Uzbekistan can take a number of steps to improve supply- and demand-side energy efficiency. On demand-side, the Government can continue investing in energy efficiency improvements in industry and agriculture, two of the largest and most inefficient end-users of electricity in Uzbekistan. In addition, scaling-up of energy efficiency improvements in other sector, such as residential and public buildings, are also expected to yield significant energy savings. On supply-side, Uzbekistan can focus more on investments in efficient generation technologies, further reduction of T&D losses and capture and utilization of flared gas.

### **Bolster Industrial and Agricultural Energy Efficiency**

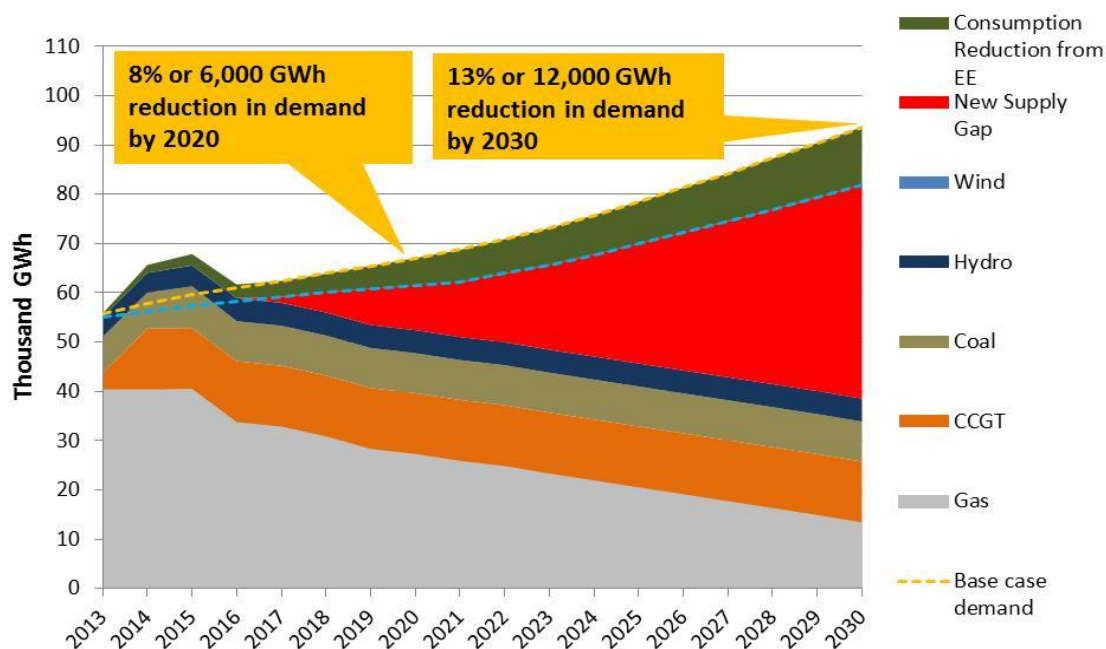
Section 3 identified the industrial and agricultural sectors as two sectors where improvements in energy inefficiency would yield largest energy savings. Energy efficiency is the least-cost option for mitigating the supply-demand gap.

Energy efficiency measures in the agricultural and industrial sectors are estimated to cost US\$0.04/kWh, compared to the long-run supply cost of US\$0.11/kWh. Energy efficiency in these sectors could reduce the electricity demand by 13 percent (12,000 GWh) by 2030 and, thus, avoid the need for 1,900 MW of new generation capacity. Figure 4.1 and Figure 4.2 show the impact of energy efficiency improvements in agricultural and industrial sectors on electricity consumption and peak load.

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<sup>59</sup> Current export tariffs in the range of US\$0.035-0.040/kWh.

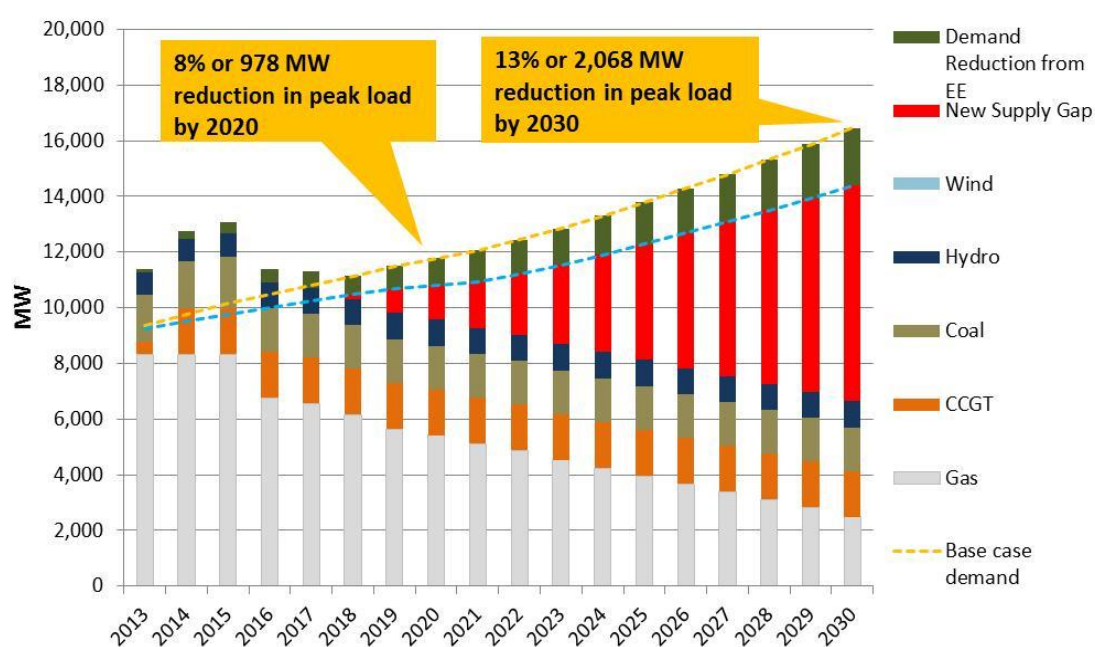
**Figure 4.1: Effect of Agricultural and Industrial Energy Efficiency Measures on Electricity Consumption**



Source: Bank team estimate.

Note: Assumes 25 percent reduction in agricultural electricity consumption by 2031 and a 15 percent reduction in industrial electricity consumption by 2021.

**Figure 4.2: Effect of Agricultural and Industrial Energy Efficiency Measures on Peak Load**



Source: Bank team estimate.



### ***Investments in industrial energy efficiency***

The cement, machinery and mining sectors have the highest potential for electricity savings in the industrial sector. While data are not available to do an analysis of the magnitude of potential savings opportunities across these sectors, survey data suggests that there are a few specific areas in which improvements would be most beneficial. These are improvements to industrial motor systems and process integration, upgrading steam systems and implementing combined heat and power systems.<sup>60</sup>

In December 2011, the World Bank initiated a US\$25 million energy efficiency project that established a credit facility to finance energy efficiency improvements in industrial enterprises in Uzbekistan. The project on-lends money to state and private banks in Uzbekistan to finance energy efficiency improvements in industrial enterprises.<sup>61</sup> It is too early to measure results and draw lessons learned, but it is clear that continued investments in energy efficiency in the industrial sector are important to help improve winter supply reliability, overcome the emerging electricity supply-demand gap and improve industrial competitiveness.

US\$170 million of investments in improvements of industrial energy efficiency over next 10 years are estimated to result in 15 percent reduction of industrial electricity consumption by 2022. The investment would save a total of US\$7.7 billion over a 10-year period (or 1.2 percent of cumulative GDP).<sup>62</sup>

### ***Investments in agricultural energy efficiency***

The largest energy efficiency potential in the agricultural sector is in irrigation pumping. Almost all irrigation in Uzbekistan relies on water that is pumped from the rivers to the fields. Given the deteriorated and inefficient pumping infrastructure, energy and water efficiency in agriculture could be improved in two ways: (a) efficiency improvements of the water pumping infrastructure, such as replacement of pumps or rehabilitation of pumping stations, and (b) measures reducing the amount of water for crop irrigation.<sup>63</sup>

The Government has already invested US\$14 million in irrigation pump modernization program to improve energy efficiency of the agricultural sector. If the Government invests additional US\$184 million over a 20-year period, it is estimated to result in 25 percent reduction of agricultural energy consumption by 2030. Those investments could save US\$4.6 billion over a 20-year period (0.3 percent of cumulative GDP).<sup>64</sup>

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<sup>60</sup> Energy Efficiency Strategy for Industrial Enterprises in Uzbekistan, World Bank, April 2012.

<sup>61</sup> World Bank, Project Appraisal Document on a Proposed Credit In the Amount of SDR 16.5 Million (US\$25 Million Equivalent) to the Republic of Uzbekistan for an Energy Efficiency Facility for Industrial Enterprises Project (UZEEF), May 21, 2010, pp. 4-5.

<sup>62</sup> Bank team estimate.

<sup>63</sup> CAREC Power Sector Master Plan, ADB, Feb. 2012.

<sup>64</sup> Bank team estimate.

## **Scale up Efforts Targeting Energy Efficiency Improvements in Residential and Public Sectors**

The Government can further improve demand-side energy efficiency by improving end-use efficiency in residential, public and other sectors. The assessment of energy efficiency potentials for public and residential sectors in other CIS countries (with similar type of residential buildings and public facilities) confirmed that substantial energy savings can be realized by investing in energy efficient retrofits of residential multi-apartment buildings and public facilities as well as implementing other Demand Side Management (DSM) policy measures. Therefore, as a starting point, the Government should consider conducting an assessment of the energy efficiency potential in those sectors.

### **Invest in Supply-side Energy efficiency**

Uzbekistan has opportunities to improve supply-side energy efficiency by: (a) replacing old gas-fired power plants; (b) reducing transmission and distribution losses (see Section 4.1); and (c) capturing and utilizing gas flared in oil and gas production (see Section 4.4).

### ***Invest in more efficient fossil-fuel based generation technologies taking into account diversification opportunities***

Construction of new generation capacity to replace old power plants and meet the growing demand is also a good opportunity to increase energy efficiency. Because of low efficiency, the old gas-fired TPP fleet consumes substantially more natural gas than would be needed to produce the same amount of electricity if all gas-fired TPPs were replaced with modern CCGTs. UE could use the inefficient plants to meet the peak demand. Thus, UE should consider conducting a study to estimate the marginal cost of supply for inefficient plants vs. the cost of un-served energy. Efficiency considerations should also be taken into account when deciding whether to convert existing gas-fired units into coal-fired and constructing new coal-fired units (see Section 4.4 for details).

### ***Assess technical and economic viability of various gas capture and utilization options***

In 2009, with the assistance of the Global Gas Flaring Reduction (GGFR) Partnership, UNG prepared the Associated Gas Recovery Plan (AGRP), which provided information on the existing sources of associated petroleum gas (APG) flaring and venting, defined potential technical solutions for utilizing the flared gas, and provided initial estimates of investment needs. UNG estimates that around US\$500 million of investments will be required for efficient utilization of APG.

UNG has already proposed a flare gas recovery project, which will aggregate and transport APG from Umid, Kruk, Western Kruk, Sarikum and Yangi Darbaza oil fields to large scale oil and gas processing facilities, where it will be processed for distribution to gas pipelines. This project might be able to receive certified emissions reductions (CERs) under the Clean Development Mechanism, which could make it economically viable for UNG.

Going forward, the Government needs to conduct detailed feasibility studies for potential technical solutions, outlined in the AGRP, in order to select the economically most viable options for reducing gas flaring and generating economic benefits for the

country. The Government should also consider conducting additional comprehensive techno-economic studies to identify viable options for capture and utilization of gas at other sites.

### **4.3 Secure Financing for Large Required Investments**

The Government can secure financing for investments by pursuing contract-based IPPs, improving prioritization of investments and increasing UE's ability to self-finance larger share of required investments.

#### **Pursuing Contract-based IPPs**

In order to attract private investments in the power sector to leverage UE funds, the Government may consider contract-based IPPs. Regulation by contract may be more appealing to private investors given lack of experience and capacity for economic regulation, or if there are concerns about the subjectivity of regulation and political interference in regulatory decision-making. Those contracts may provide better accountability, reliability and transparency (for both public and private parties of the contract) by fixing the rules for service standards, remuneration, monitoring, enforcement, and dispute resolution in the contract.

Attracting contract-based IPPs may limit the number and scope of legal, institutional and regulatory changes required. Therefore, the Government should examine changes required to existing legislation and regulations to attract competitive and high quality bids for IPPs.

The Government could also enhance private investor interest by increasing disclosure of information and transparency. The information and data about operating and financial performance of UE/UNG and its subsidiaries, ongoing and planned investments as well as sector analysis and reports, are such examples.

Additionally, launching an IPP for a power plant in Uzbekistan would also require substantial training within the Government and, in particular, within the agencies that will procure, negotiate, and manage the contract once it is signed.

#### **Improving Prioritization of Investments Based on Sound Cost-Benefit Analyses**

Governments are typically unable to finance all of the investments included in their investment plans. It is therefore important to ensure that the most critical investments are prioritized, and are first in line for whatever funding is available.

Techno-economic and feasibility studies are the first step to selecting the projects with highest economic benefits within existing funding constraints. Feasibility studies can help the Government decide which projects have the highest economic value for Uzbekistan, and can help private investors determine which projects are of most interest to them.

#### **Explore Options to Increase UE Revenues**

The loss reduction efforts will allow UE to improve operating efficiency and increase revenues. However, the Government should also consider options for tariff increase as a means to increase UE cash flows. As noted in Section 3.3, the average electricity tariff in Uzbekistan is 50 percent below the long-run supply cost, which precludes UE from generating sufficient cash to finance a larger share of required capital

investments from own funds and increasing the borrowing capacity through its own balance sheet. The Government has made some progress to bring the tariffs to cost-recovery levels, but the real increase was limited given the inflation rates in the country in 2004-2012.

If future tariff increases are at a rate to mitigate the impact of inflation on costs and losses remain at current levels, then UE will be able to finance only up to 30 percent of the total investments required (US\$1.5 billion) until 2020. However, if annual tariff increase exceeds the annual rate of inflation by 4 percent and losses reduce from 20 to 13 percent of net supply, then UE can finance up to 50 percent (US\$2.5 billion) of required capital investments with unsecured financing.

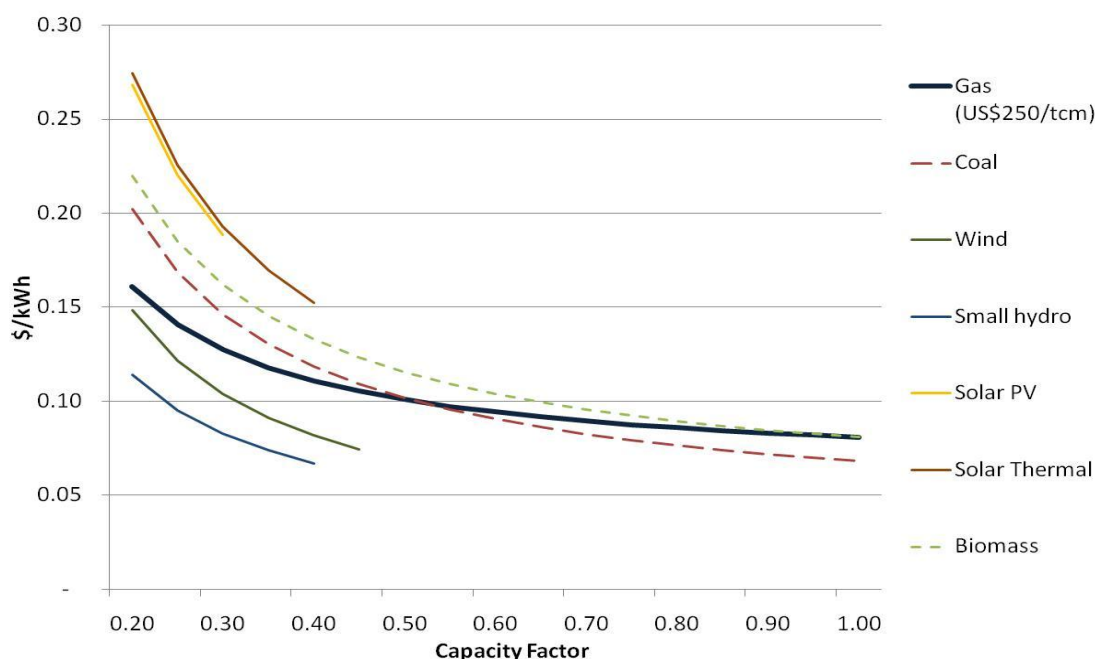
Before a decision to further increase tariffs is made, it is important to understand current electricity use and spending of poor and vulnerable households on electricity as well as determine the impact of tariff increases on their welfare. In addition, strategies of poor households to cope with increasing costs of electricity need to be understood. An assessment of the usefulness of different measures that might either already exist or can be put in place to support households that have difficulties paying electricity bills should be undertaken. Such measures could include social assistance programs or changes in the tariff structure, among others. Moreover, diversification of generation mix and increased efficiency of gas-fired generation could create additional gas export revenues, which might be used to finance a portion of required power sector investments and mitigate the impact of increasing electricity tariffs on the poor.

#### **4.4 Diversify Electricity Generation Mix**

As part of the investment prioritization, the Government should start planning for diversification of electricity generation mix to reduce near-complete dependence on natural gas and use it for higher value exports, improve supply reliability and reduce vulnerability of the power sector to climate change. Diversification of generation mix will also enable the Government to use revenues from increased gas exports to finance much needed power sector capital investments.

In addition to trade opportunities with Central Asian countries, there are several alternatives to gas-fired generation the Government might consider. The levelized energy costs (LEC) of those alternatives will very much depend on the cost of capital, fuel prices and CO<sub>2</sub> price. Figure 4.3 compares illustrative economic costs of various generation options. The Government should consider conducting more detailed studies of the economic viability of those options and trade-offs involved.

**Figure 4.3: Comparing the Economic Costs of Renewable Energy and Fossil Fuel Technologies, inclusive of CO<sub>2</sub>**



Source: Bank team assessment based on data from International Energy Agency (IEA) and OECD Nuclear Energy Agency (NEA), Projected Costs of Generating Electricity, 2010 Edition, and UE estimates

Note: Biomass is assumed to have zero net carbon emissions

In order to diversify the generation mix, the Government has plans to increase share of coal and renewable energy in the supply mix in order to reduce reliance on natural gas and make use of its significant and inexpensive coal resources.

### Coal-based generation

Work is underway to increase the share of coal-based (primarily lignite) electricity supply. Specifically, UE is currently converting five units of the Novo-Angren TPP to start burning coal in 2013 and plans to convert the remaining two units by the end of 2016. The first five units have a combined available capacity of 1,404 MW and the conversion is expected to cost approximately US\$181/kW. Units 6 and 7 have a combined available capacity of 560 MW and the conversion is expected to cost approximately US\$507/kW.<sup>65</sup> It is clear that the capital cost of converting natural gas-fired plants to coal-fired is significantly lower than the cost of building modern and efficient plants, which is estimated at approximately US\$2,000/kW.

However, there are other important issues such as efficiency and environmental impacts, which should be considered while deciding on conversion of gas-fired plants to coal and when planning further increase of coal-fired generation. These include:

<sup>65</sup>"Modernization in power sector, attraction of investments for joint projects and implementation of projects," UE Presentation, 2011.

Efficiency of converted vs. new coal-fired plants and environmental impacts: When gas-fired plants are converted to coal, their generation is likely to reduce. Also, conversion of natural gas plants to coal might reduce the efficiency of the plant. This would result in lower plant efficiencies. It is very important given that most of Uzbekistan's existing thermal plants already have efficiencies below 35 percent. By comparison, new lignite plants can achieve efficiencies of up to 38 percent for plants under 300 MW, and up to 41 percent for larger plants.<sup>66</sup>

Also, coal-fired CHPPs could be more efficient than TPPs and more environmentally friendly. CHPPs generate electricity and capture and distribute the waste heat from electricity generation to provide heat for buildings or industrial processes. Thus, CHPPs would also have lower greenhouse gas (GHG) emissions per unit of output. However, coal-fired CHPPs close to residential areas might have public health implications. Thus, considering a coal-fired CHP for industrial area may be a better option. Of the three CHPPs currently in operation in Uzbekistan, the Fergana CHPP is located in an industrial area, while Mubarek CHPP and Tashkent CHPP are located in residential areas.<sup>67</sup>

Type of demand coal plants will be serving: Coal plants would likely need to be run as base-load plants, and UE might be unable to ramp these plants up and down to follow load the way that it currently does with its gas-fired fleet. This could reduce efficiency and jeopardize reliability if other generation is not built to follow load or regional trade with hydro-rich neighbors does not increase.

Carbon capture and sequestration to increase oil recovery and reduce environmental impact of coal plants: Increasing the share of coal in the generation mix will also result in increased levels of CO<sub>2</sub>, SO<sub>x</sub>, NO<sub>x</sub> and particulate emissions. However, emissions can be mitigated through carbon capture and storage (CCS) technology. Captured CO<sub>2</sub> can be transported to oil fields and used in enhanced oil recovery (EOR). EOR with CO<sub>2</sub> is the process of injecting the captured CO<sub>2</sub> into oil fields to reduce the viscosity of the oil, making it easier to remove. Many of Uzbekistan's oil fields are depleted, and injecting captured CO<sub>2</sub> emissions into these fields could potentially improve oil recovery and sequester the CO<sub>2</sub> underground. Injection of CO<sub>2</sub> can also enhance the recovery of natural gas. The following TPPs are closest to oil and gas fields, and therefore could be potential candidates for integrated CCS with EOR systems: Talimardjan and Mubarek plants in the Bukara-Khiva region and the Fergana, Angren, and Novo-Angren plants in the Fergana region.<sup>68</sup> The Government should take into account that implementation of CCS in old plants tends to have higher costs compared to CCS retrofits in new, highly efficient plants with large capacities.<sup>69</sup> Thus, a detailed techno-economic study will be required to assess the viability of CCS as applied for purposes of EOR.

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<sup>66</sup> Bank team.

<sup>67</sup> Bank team.

<sup>68</sup> Bank team.

<sup>69</sup> Finkenrath, Matthias, Julian Smith, and Dennis Volk. CCS Retrofit: Analysis of the Globally Installed Coal-Fired Power Plant Fleet, International Energy Agency (IEA), 2012. [http://www.iea.org/papers/2012/CCS\\_retrofit.pdf](http://www.iea.org/papers/2012/CCS_retrofit.pdf).

## Renewable energy

Most of the renewable energy options shown in Figure 4.3 are higher cost than gas. However, as Uzbekistan's opportunity cost for gas increases (due to rising gas export prices) and/or capital costs for renewable energy continue to follow the decreasing trend, renewable and other alternatives may start to look more attractive.

The Government has indicated its commitment to increase the share of renewable energy in the generation mix. Specifically, it is planning to construct 400 MW of small HPPs, a 100 MW solar PV plant and a 100 MW wind farm. Moreover, the World Bank is currently preparing a project to provide financing and technical assistance for development of small-scale renewable energy resources in the agricultural sector.<sup>70</sup> Box 4.1 below presents a discussion of renewable energy initiatives related to small hydropower, wind and solar energy.

### Box 4.1: Hydro, wind and solar energy initiatives in Uzbekistan

**Small hydropower:** Small-scale hydropower resources are particularly well-suited for deployment to serve agricultural electricity demand. Due to high electricity demand by the agricultural sector for water pumping, SHPPs have been identified as promising alternatives for this sector, as the season of highest electricity generation from these resources would coincide with highest demand for electricity by the agricultural sector.<sup>71</sup>

Currently, a number of SHPPs are under construction with total installed capacity of 50 MW and total cost of US\$150 million.

**Wind:** Due to the geographical location of Uzbekistan and climate conditions, wind power in the country is seasonal. Country-wide distribution of the duration of energy active wind speeds (3 m/s and more) is similar to the distribution of average speeds. The maximum duration (6-8 thousand hours/ year) is characteristic for foothill zones of mountain ridges. In deserted areas, such speeds are observed 3-4 thousand hours/year. Bukhara, Navoyi, Tashkent regions, and Karakalpakstan are estimated to have the largest wind power potential.<sup>72</sup>

The Government is planning to construct wind plants in prospective areas with total installed capacity of 100 MW by 2020 with estimated cost of up to US\$250 million. In 2013, UE plans to secure the Government approval for the Program for Wind Power Development until 2020. In 2011, the Government announced the tender for construction of a 0.75 MW wind power station in Tashkent area; the construction is expected to be completed by the end of 2013. The total estimated cost of the project is US\$1.8 million.<sup>73</sup>

<sup>70</sup> World Bank "Project Appraisal Document on a Proposed Grant in the Amount of US\$12.70 Million to the Government of Uzbekistan for a Sustainable Agriculture and Climate Change Mitigation Project (GEF) (P127486)," February 16, 2012.

<sup>71</sup> Eschanov et al., Potential of Renewable Energy Sources in Uzbekistan, *Journal of Knowledge Management, Economics and Information Technology*, December 2011.

<sup>72</sup> CAREC Power Sector Master Plan, ADB, Feb. 2012.

<sup>73</sup> RIA News Agency, October 17, 2011.

**Solar energy:** Data from multi-year observations from solar activity measurement and monitoring stations in Uzbekistan show that the duration of sunshine varies between 2,410 and 3,090 hours/year, with seasonal fluctuations of 11 hours/day in summer and 4 hours/day in winter.<sup>74</sup>

Development of solar energy in Uzbekistan might be facilitated by the availability of local manufacturers, assembling solar PV panels and producing solar heaters, and manufacturers of input such as wires and cables, glass, insulating materials, support structures, and other components. The country has around 40,000 m<sup>2</sup> of solar heaters installed. However, the penetration of solar energy technologies is limited to several off-grid installations, primarily including solar heaters used by industrial enterprises and households in rural areas.<sup>75</sup>

In order to bolster industrial-scale solar energy development, the Government is pursuing construction of a solar power plant (technology details are not available) with total installed capacity of up to 100 MW and total cost of US\$350 million. The plant is to be constructed in partnership with Russian Lukoil and ADB. The Government is also pursuing establishment of the National Institute for Solar Energy, which will become an R&D centre for solar energy and support implementation of solar energy projects.<sup>76</sup>

The efforts to increase the share of renewable energy should be continued with improvements in financial planning and techno-economic assessment of renewable energy potential and specific projects. In particular, there has been no detailed assessment of the potential for renewable energy in the country. Therefore, the Government should consider conducting such an assessment, including assessment of economic and financial viability of renewable energy, advantages and disadvantages of renewable energy versus conventional fossil-fuel based generation, analysis of key barriers impeding development of renewable energy and policy options to promote them.

When planning diversification of generation mix, the Government should also take into account that renewable energy will not provide base-load replacement capacity or substitute existing gas-fired TPPs or CHPPs. Most renewable energy options shown on Figure 4.3 have the disadvantage of being intermittent or “non-dispatchable” and, therefore, cannot be used to meet peak demand. However, some renewables, such as biomass or storage hydro may be useful for meeting peak.<sup>77</sup> Meanwhile, renewable energy provides significant environmental benefits and increases diversification of supply.

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<sup>74</sup> CAREC Power Sector Master Plan, ADB, Feb. 2012.

<sup>75</sup> The Outlook for Development of Renewable Energy in Uzbekistan, UNDP, 2007.

<sup>76</sup> PV-Magazine.com, October 27, 2011.

<sup>77</sup> Small hydro plants are typically run-of-river plant, without any storage. Electricity generation depends on water flows.



**Table 4.2: General advantages and disadvantages of renewable energy versus other generation options as applied to Uzbekistan**

Options	CAPEX	OPEX	Dispatchability
Gas-fired TPPs or CHPPs	Low	High	+
Coal-fired TPPs or CHPPs	Moderate	Moderate	+
Large and mid-size HPPs	Moderate	Low	+ (if storage)
SHPPs	Moderate	Low	-
Wind	Moderate	Low	-
Solar	High	Moderate	-

Source: Bank team.

## 4.5 Start Adapting to Climate Change

The Government should consider a number of adaptation measures that can be introduced over time to enhance energy security, better protect against climate change impacts and align the power sector with economic consequences of its environmental impacts. Those ‘no-regrets’ actions include:

### Diversify the Electricity Generation Mix

The power sector vulnerability analysis indicates that climate change is likely to require additional investments for meeting growing electricity demand under forecasted climate changes, likely to reduce thermal generation and increase variability of hydropower generation. Thus, diversification of generation into renewables (e.g. solar and wind) can help to reduce vulnerability of Uzbekistan’s power sector to climate change. The LECs of various generation options suggests that those are costly compared to conventional gas or coal-fired generation, but with maturing technologies the costs will further decrease. The Government is already committed to developing solar and wind projects and should continue its efforts.<sup>78</sup>

Regional electricity trade within the Central Asia Power System is an additional mechanism for increasing supply diversity and reducing risks and costs associated with dependence on thermal power plants.

### Continue Improving Energy Efficiency

The study on Assessment of Uzbekistan’s Energy Sector Climate Vulnerability, Risk and Adaptation indicated that the power supply scenarios with higher levels of energy efficiency, including DSM, are a least-cost option to meet the incremental demand and help to reduce the greenhouse gases. Energy efficiency measures in the agricultural and industrial sectors are estimated to cost 2.5 times less than the cost for new power generation, and implementing energy savings measures in the residential sector can help mitigate the effect of electricity tariff increases on the population. Therefore, the

<sup>78</sup> World Bank, Climate Vulnerability, Risk and Adaptation Assessments. Helping Countries Prepare an Effective Power Sector Response: Focus on Uzbekistan Draft Final Report, June 2012.

Government should expand its efforts towards increasing the level of energy efficiency and energy savings throughout the economy.

### **Improve Water Resource Management**

As mentioned in Section 3, climate change impacts on hydrology might result in reduced water availability for electricity generation at thermal power plants and increased competition between water demand for agricultural and electricity generation needs. The Government could start implementing measures today to mitigate this problem by (i) planning to replace old thermal plants with new plants using CCGT technology (less water intensive), and (ii) design those as closed-loop systems to reduce significantly the volume of water required.

Management of potential conflicts between irrigation and power generation could include improvements in irrigation systems and on-farm management to increase water productivity. Such investments have additional benefits of increasing agricultural incomes and reducing environmental consequences of water-logging.<sup>79</sup>

### **Improve Facility Maintenance and Disaster Risk Management**

A range of additional adaptation measures were identified to address extreme events, loss of operational efficiency, and environmental impacts, largely focused at the plant level. Many measures are “no regrets” options since they offer climate benefits while ensuring safety and economic benefits. Specifically, the Government may consider: (a) improving existing asset efficiency through clearing/redesigning trash racks, upgrading turbines and generators, replacing equipment to reduce water losses (shut-off valves), improving the ‘aprons’ below dams to reduce erosion, using improved weather data to optimize operation; (b) identifying key energy facilities/assets at risk and plan proactive action; (c) investigating applicability of weather change insurance to energy sector risks and some other measures.<sup>80</sup>

### **Improve Knowledge and Strengthen Key Responsible Institutions**

The ability to monitor and plan for climate change, and, ultimately, the ability to adapt, will depend equally on management capacity and investments. Key areas for strengthening knowledge and institutions are:

- Cross-sectoral consultations and joint planning, particularly in areas of water and disaster risk management.
- Strengthening base data on key climate indicators by: (i) upgrading weather and hydrological monitoring network; (ii) ensuring all historical and observed climatologically and hydrological data are compiled in digital databases and freely made available to energy sector stakeholders; and (iii) encouraging further research on climate change (e.g., at academic and research institutes).

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<sup>79</sup> World Bank, Climate Vulnerability, Risk and Adaptation Assessments. Helping Countries Prepare an Effective Power Sector Response: Focus on Uzbekistan Draft Final Report, June 2012.

<sup>80</sup> World Bank, Climate Vulnerability, Risk and Adaptation Assessments. Helping Countries Prepare an Effective Power Sector Response: Focus on Uzbekistan Draft Final Report, June 2012.

The energy sector is highly dependent on accurate climate information for forward planning and management. Demand and supply pressures are projected to change with the climate. In order to adapt to these shifts, better information services are needed, including strong basic forecasting, long-range forecasting, satellite imaging and climate change projections covering changes in average and extreme climatic conditions.<sup>81</sup>

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World Bank, Climate Vulnerability, Risk and Adaptation Assessments. Helping Countries Prepare an Effective Power Sector Response: Focus on Uzbekistan Draft Final Report, June 2012.

## 5 Current Engagement and Potential Role of the World Bank in Helping the Government to Address Power Sector Challenges

The World Bank has an ongoing energy sector program in Uzbekistan aimed at increasing the efficiency of infrastructure and reliability of supply needed for robust and sustainable economic development. Specifically, the World Bank is supporting the Government to implement three investment operations and a number of technical assistance projects. The ongoing investment operations include:

- **US\$35 million Energy Efficiency Facility for Industrial Enterprises** (including IDA credit of US\$25 million) to improve energy efficiency of small and medium sized industrial enterprises in Uzbekistan and thereby reduce environmental impacts on climate change and conserve energy. The project is financing: (a) credit lines to local commercial banks to on-lend to industrial enterprises for energy efficiency investments and (b) capacity building for energy efficiency.
- **US\$170 million Talimarjan Transmission Project** (including IBRD loan of US\$110 million) to improve the reliability of electricity supply to residential and business consumers in South-Western Uzbekistan (Samarkand, Kashkadarya, Navoyi, and Bukhara regions) with a total population of over 4 million people. The project is supporting construction of: (a) 220 km single-circuit 500 kV transmission line from Talimarjan TPP to Sogdiana substation; (b) 500/220 kV open switch-yard at Talimarjan TPP; (c) a bay extension at Sogdiana substation; (d) a 500 kV connection line from the 500/220 kV open switch-yard at Talimarjan TPP to Karakul-Guzar transmission line; and (e) institutional strengthening of UE, including project monitoring and supervision, financial management and procurement.
- **US\$246 million Advanced Electricity Metering Project** (including IBRD loan of US\$180 million) to reduce commercial losses of three regional power distribution companies (Tashkent City, Tashkent Oblast and Syrdarya Oblast) by improving their metering and billing infrastructure, and commercial management systems. The project is supporting: (a) supply, installation and commissioning of modern metering infrastructure for 1.2 million low voltage customers, including meters, communication systems, hardware and software for data management system; (b) energy data management, billing and archive system; and (c) improvements in management efficiency and project implementation support.

Additionally, the World Bank is providing technical assistance through a number of trust fund financed activities to improve energy efficiency:

- **Development of Energy Efficiency Strategy for manufacturing enterprises.** The key focus of the strategy is: (a) to assess energy consumption patterns of industrial manufacturing enterprises; (b) develop a handbook for proven energy efficient technologies for manufacturing sector; (c) identify practices in targeting and improving energy efficiency in manufacturing enterprises; (d) assess institutional capacity to implement energy efficiency measures; and (e) recommend demand-side management practices.

- **Support with reduction of gas flaring.** The Global Gas Flaring Reduction Partnership (GGFR) was supporting the Government to reduce flaring of associated gas at oil fields. Specifically, a Clean Development Mechanisms (CDM) project is under development for use of associated gases at a number of oil fields (Umid, Kruk, Western Kruk, Sarikum and Yangi Darbaza). The project is aiming to switch to a closed system of oil treatment to allow accumulation of associated gases in gas compression units. It is planned to supply the gas to treatment plants of nearby fields and later on to end-users through main gas pipelines.

Given the above challenges, the Government requested the World Bank to continue supporting improvement of energy infrastructure and energy efficiency as outlined in the Country Partnership Strategy (CPS) for FY 2012-2015. In particular, the Government requested to support the following:

- **Energy efficiency improvement of industry** through investments in replacement of key energy-consuming equipment and other energy efficiency measures as well as technical assistance.
- **Rehabilitation and modernization of power distribution network** to improve reliability of the distribution network. Potential investments would cover the key distribution infrastructure (e.g. transformers, meters) and further roll-out of advanced metering, billing infrastructure, and commercial management systems in other regions of the country.
- **Rehabilitation and expansion of transmission networks** to improve reliability of supply, including rehabilitation of transmission infrastructure (e.g. substations, transmission lines), and construction of additional transmission capacity to serve increasing demand.
- **Reduction of gas flaring.** Further dialogue with the Global Gas Flaring Reduction Partnership (GGFR) and Carbon Financing Mechanisms. Uzbekneftegaz confirmed its participation in the GGFR Partnership for 2010-12, aiming to reduce gas flaring from its oil production.

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## Appendix B: Institutional, Legal and Regulatory Framework of the Power Sector

Key legislation related to power sector includes:

- **Decree On Deepening of Economic Reforms in the Energy Sector of Uzbekistan (2001).** This presidential decree identified government priorities for reforms in the power sector. The decree called for the de-monopolization of energy enterprises, the reduction of state regulation and the promotion of competition in the power sector. It also called for provision of open access to high voltage transmission lines. Unfortunately, these objectives have not yet been fully realized. UE remains a vertically-integrated monopoly under government control. Efforts to privatize UE subsidiaries have been unsuccessful.
- **Law On Measures for Organizing the Activities of the UE (2001).** This law sought to bring reforms based on the priorities of the decree to deepen economic reforms (described above). The law:
  - Transferred power generation assets from the Ministry of Energy and Electrification to the newly created UE.
  - Created the power sector technical regulator UzGosEnergoNadzor.
  - Made it possible for UE to offer private investors up to 49 percent ownership in TPPs and distribution companies, and up to 75 percent ownership of companies involved in power sector design, construction and repairs. As noted above, however, privatization efforts have not yet been successful.
  - Incorporated UzbekUgol, the national coal company, under UE.
- **Law On Improving the Activities of Economic Management Agencies (2003) and On Improved Organization of UE Activities (2004).** These laws:
  - Separated the high-voltage transmission networks into five zonal branches, united under Uzelectroset.
  - Transferred distribution network assets to separate, regional distribution companies.
- **Law On Measures to Improve the Payment Mechanism for Using Electric Energy (2004) and Law On Additional Measures to Strengthen the Accounting and Control system for Selling and Using Electric Energy (2004).** The objectives of these laws were to improve the collection rates for electricity. Some progress has been made in this area, but collections are still quite low in Uzbekistan.
- **Law On Extension of the Process of De-Monopolization and Privatization for 2006-2008.** This law offered shares in 26 government-owned joint-stock companies. Fifteen percent stakes were offered in 12 power distribution companies, and 9 electricity and heating companies. The private sector involvement efforts remained unsuccessful.
- **Law On Measures Aimed at Further Deepening of the Privatization Processes and Active Attraction of Foreign Investments During the Years 2007-2010**

(2007). This law offered minority shares in UE power generating assets (the Syrdarya, Novo-Angren, Navoi, Takhiatash, Angren, Tahkent, Fergana, and Mubarek TPPs), UNG and UzbekUgol to private investors. None of these tenders were successful.

- **The Law on Electric Power (2009).** This law was intended to create a better integrated framework for regulating the electricity sector in Uzbekistan, improve energy efficiency in the sector and attract private investments. The law includes provisions to allow on-site energy generation without licensing, to allow on-site generators to sell electricity back to the grid, and established basic requirements for independent operators of electricity distribution systems.<sup>82</sup> The law also made it possible for UE to suspend electricity supply to consumers for violation of their supply agreements, or damage of electricity meters.

The power sector is regulated by multiple government agencies. The principal agencies and their responsibilities are described below:

- **The Cabinet of Ministers.** The Cabinet of Ministers governs UE through the company's Board of Directors. It is responsible for approving the development and financing of new energy resources, and licensing new power generation. The Cabinet is also responsible for assisting in the implementation of renewable energy projects.
- **Ministry of Finance (MoF).** The MoF approves electricity tariffs with input from UE and UzGosEnergoNadzor. MoF also approves financing for capital expenditure by UE and its subsidiaries.
- **UzGosEnergoNadzor.** UzGosEnergoNadzor is the technical regulator. It is an inspection agency, which enforces compliance with state standards for health protection and safety.
- **The State Committee on De-Monopolization.** The State Committee on De-Monopolization monitors competition, customer rights and financial performance in the energy sector, including power.

Other government agencies involved in the power sector, and their roles are as follows:

- **Ministry of Economy (MoE).** The MoE is responsible for evaluating the social and economic impact of power tariffs in the framework of overall energy policy.<sup>83</sup>
- **Ministry for Foreign Economic Relations.** The Ministry for Foreign Economic Relation's objective is to ensure that Uzbekistan realizes its policy in foreign

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<sup>82</sup> United Nations Economic and Social Commission for Asia and the Pacific, Law on the Rational Use of Energy (1997), Compendium on Energy Conservation Legislation in Countries of the Asia and Pacific Region, February 9, 1999. Accessed May 9, 2012, <http://www.unescap.org/esd/publications/energy/compend/ceccpart4chapter12.htm#1>

<sup>83</sup> Asian Development Bank, Electricity Sectors in CAREC Countries: A Diagnostic Review of Regulatory Approaches and Challenges, 2005, p. 84

trade, and assisting in the development of a favorable investment climate for foreign investors.<sup>84</sup>

- **State Committee on Architecture and Construction.** The State Committee on Architecture and Construction is responsible for permitting state construction works and drafting laws related to construction and planning. The Committee is also responsible for preparing proposals for divestment of shares of state construction companies and procuring materials and services for government construction projects.<sup>85</sup>

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<sup>84</sup> Government Portal of the Republic of Uzbekistan web site, Ministry for Foreign Economic Relations, Investments and Trade of the Republic of Uzbekistan. Accessed May 10, 2012, <http://www.gov.uz/en/authorities/ministries/1309>

<sup>85</sup> Government Portal of the Republic of Uzbekistan web site, State Committee of the Republic of Uzbekistan for Architecture and Construction. Accessed May 10, 2012, [http://www.gov.uz/en/authorities/state\\_committees/1325](http://www.gov.uz/en/authorities/state_committees/1325)

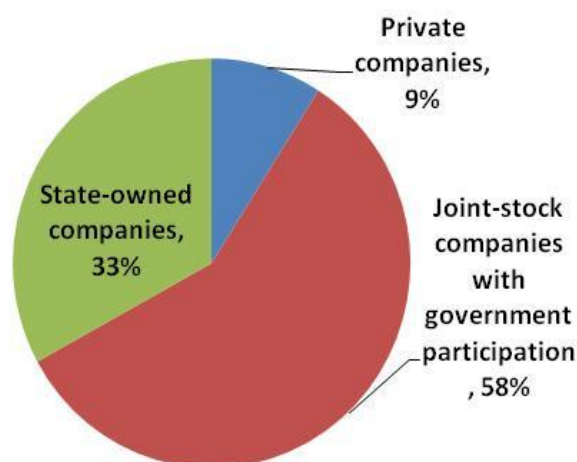
## Appendix C: Heating Sector

### Structure, Legal and Regulatory Framework

The heating sector in Uzbekistan consists of 33 heat supply companies. Ten of these companies generated both electricity and heat. Most of the service providers are joint-stock companies owned by the Government and a small number of private companies. Appendix Figure C.1 shows the ownership structure of heating sector companies.

**Appendix Figure C.1: Heating Company Types**

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Source: Ilhom Djalalov, "District Heating Systems in Uzbekistan," Ministry of Finance of Uzbekistan, PowerPoint Presentation, 2010.

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Other organizations involved in provision of heating services include: (a) municipal heating utilities, (b) UE-owned CHPPs, (c) industrial enterprises with their own boiler houses (BH), which also provide heat to neighboring customers, (d) state-owned boiler houses that provide heat and hot water for public buildings, and (e) housing owner associations.

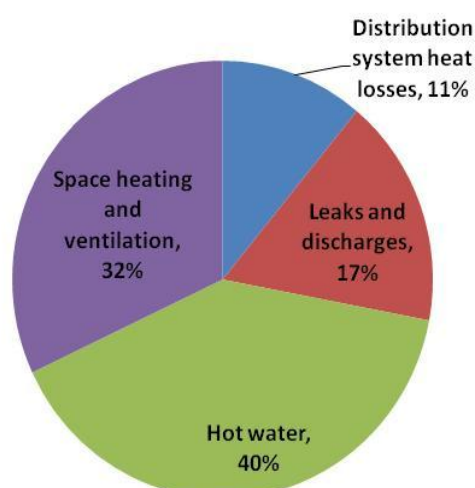
Around 25 percent of heat supplied is generated by CHPPs. The three CHPPs are in Fergana, Mubarek and Tashkent. All are owned by UE and sell the heat directly to large customers or to district heating companies.

About 80 percent of consumers are connected to district heating (DH) systems. This is relatively high compared with other CIS countries, in which on average 70 percent of consumers are connected to DH systems. The residential sector accounts for 70 percent of heat consumption.<sup>86</sup> The largest end-use of district heat is for domestic hot water, which accounts for 40 percent of heat supplied, followed by space heating and ventilation, which use 32 percent of heat supplied. Appendix Figure C.2 below shows the heat consumption structure by type of use.

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<sup>86</sup> Final Report Technical Assistance to the Republic of Uzbekistan for Energy Needs Assessment, Volume I: Review and Assessment of Energy Needs, ADB, October 29, 2004

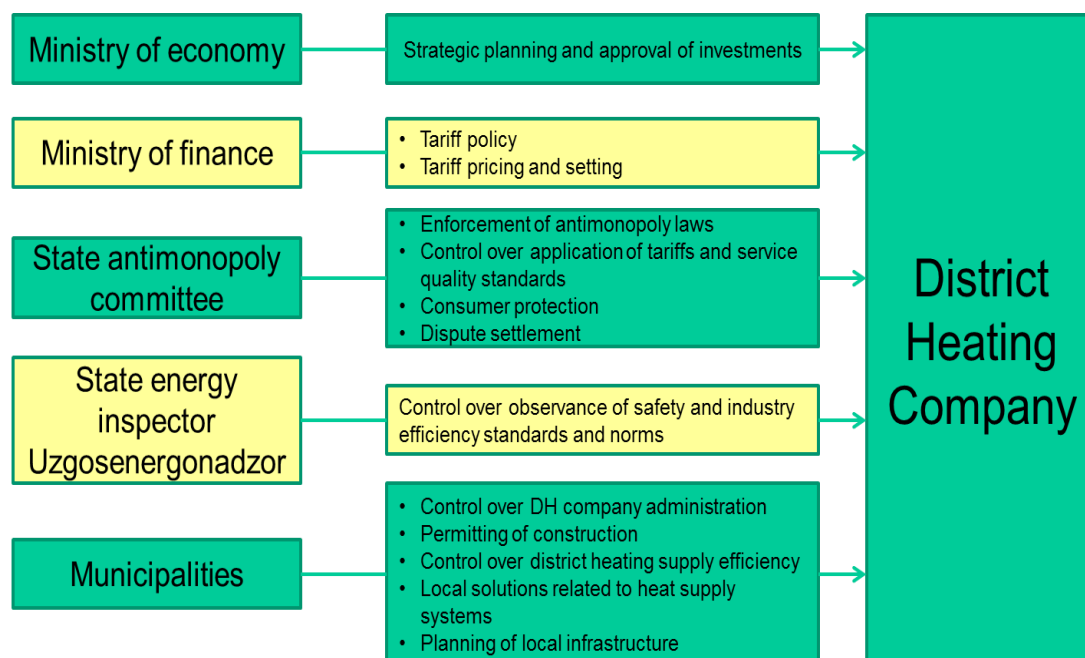
**Appendix Figure C.2: Heat consumption by end-use**



Source: Final Report Technical Assistance to the Republic of Uzbekistan for Energy Needs Assessment, Volume I: Review and Assessment of Energy Needs, ADB, October 29, 2004

Heating is regulated under the Law on Natural Monopolies, which specifies that tariffs and other activities of the companies in this sector are regulated by the Government. Several different organizations within the Government regulate district heating. These organizations and their functions are shown in Appendix Figure C.3.

**Appendix Figure C.3: Regulation in the district heating sector**



Source: Ilhom Djalalov, District Heating Systems in Uzbekistan, Ministry of Finance of Uzbekistan, PowerPoint Presentation, 2010

## Appendix D: Thermal and Hydro Power Plant Installed Capacities and Service Lives

Appendix Table D.1: TPPs and CHPPs

Plant/Unit	Fuel	Installed Capacity (MW)	Estimated Remaining Service Life (yrs)
Talimardjan TPP Unit 1	Gas	800	42
Sirdarya TPP Unit 1	Gas	300	10
Sirdarya TPP Unit 2	Gas	300	11
Sirdarya TPP Unit 3	Gas	300	12
Sirdarya TPP Unit 4	Gas	300	13
Sirdarya TPP Unit 5	Gas	300	14
Sirdarya TPP Unit 6	Gas	300	15
Sirdarya TPP Unit 7	Gas	300	16
Sirdarya TPP Unit 8	Gas	300	17
Sirdarya TPP Unit 9	Gas	300	18
Sirdarya TPP Unit 10	Gas	300	19
Novo-Angren TPP Unit 1	Gas/Coal	300	23
Novo-Angren TPP Unit 2	Gas/Coal	300	23
Novo-Angren TPP Unit 3	Gas/Coal	300	24
Novo-Angren TPP Unit 4	Gas/Coal	300	25
Novo-Angren TPP Unit 5	Gas/Coal	300	26
Novo-Angren TPP Unit 6	Gas/Coal	300	29
Novo-Angren TPP Unit 7	Gas/Coal	300	33
Tashkent TPP Unit 1	Gas	150	3
Tashkent TPP Unit 2	Gas	150	3
Tashkent TPP Unit 3	Gas	150	3
Tashkent TPP Unit 4	Gas	150	3
Tashkent TPP Unit 5	Gas	150	4
Tashkent TPP Unit 6	Gas	155	5
Tashkent TPP Unit 7	Gas	165	5
Tashkent TPP Unit 8	Gas	165	6

Plant/Unit	Fuel	Installed Capacity (MW)	Estimated Remaining Service Life (yrs)
Tashkent TPP Unit 9	Gas	150	7
Tashkent TPP Unit 10	Gas	165	8
Tashkent TPP Unit 11	Gas	155	8
Tashkent TPP Unit 12	Gas	155	9
Navoi TPP Unit 3	Gas	150	3
Navoi TPP Unit 4	Gas	150	3
Navoi TPP Unit 8	Gas	160	6
Navoi TPP Unit 9	Gas	160	6
Navoi TPP Unit 11	Gas	210	18
Navoi TPP Unit 12	Gas	210	19
Navoi TPP Unit 1	Gas	25	3
Navoi TPP Unit 2	Gas	25	3
Navoi TPP Unit 5	Gas	50	4
Navoi TPP Unit 6	Gas	50	5
Navoi TPP Unit 7	Gas	60	5
Tachiatash TPP Unit 1	Gas	210	3
Tachiatash TPP Unit 2	Gas	210	3
Tachiatash TPP Unit 3	Gas	110	3
Tachiatash TPP Unit 4	Gas	100	7
Tachiatash TPP Unit 5	Gas	100	9
Angren TPP Unit 1	Gas/Coal	52.5	3
Angren TPP Unit 2	Gas/Coal	54.5	3
Angren TPP Unit 3	Gas/Coal	53	3
Angren TPP Unit 4	Gas/Coal	52	3
Angren TPP Unit 5	Gas/Coal	68	3
Angren TPP Unit 6	Gas/Coal	68	3
Angren TPP Unit 7	Gas/Coal	68	3
Angren TPP Unit 8	Gas/Coal	68	3
Fergana CHPP Unit 1	Gas	25	0



Plant/Unit	Fuel	Installed Capacity (MW)	Estimated Remaining Service Life (yrs)
Fergana CHPP Unit 2	Gas	50	0
Fergana CHPP Unit 3	Gas	55	2
Fergana CHPP Unit 4	Gas	55	6
Fergana CHPP Unit 5	Gas	60	10
Fergana CHPP Unit 6	Gas	60	17
Mubarek CHPP Unit 1	Gas	30	22
Mubarek CHPP Unit 2	Gas	30	23
Tashkent CHPP Unit 1	Gas	30	0
Other thermal power plants	Gas	41	0
<b>Total Installed Capacity</b>		<b>10,660</b>	

**Appendix Table D.2: Efficiencies of Existing Thermal Power Plants**

Plant	Available Capacity (MW)	Reported Efficiency
Talimardjan TPP*	772	40%
Sirdarya TPP	2,840	34%
Novo-Angren TPP	1,960	32%
Tashkent TPP	1,758	33%
Navoi TPP	1,181	30%
Tachiatash TPP	690	30%
Angren TPP	445	31%
Fergana CHPP	289	25%
Mubarek CHPP	56	30%
Taschkent CHPP	28	23%
Other TPPs	39	Not reported
<b>Weighted average efficiency =</b>		<b>33%</b>
<b>Efficiency of modern CCGTs =</b>		<b>53% - 56%</b>

Source: World Bank team calculations

\* Two additional 450 MW CCGT units are under construction at Talimardjan

**Appendix Table D.3: Hydropower plants**

Cascade/Plant	Installed Capacity (MW)
<b>Urta-Chirchik HPP cascade</b>	
Charvak	621
Chodjiket	165
Gasalkent	120
<b>Chirchik HPP Cascade</b>	
Tawak	72
Chirchik	84
Akkawak 1	34.7
<b>Kadyrin HPP Cascade</b>	
Akkawak 2	9
Kubrai	11.2
Kadyrin	13.2
Salar	11.2
<b>Tashkent HPP Cascade</b>	
Bozsui	4
Shekhantau	3.6
Burddjar	6.4
Aktepin	15
<b>Lower Bozsui HPP Cascade</b>	
Bozsui 14	10.7
Bozsui 15	7
Bozsui 16	11.2
Bozsui 17	17.6
Bozsui 18	4.4
<b>Farchad HPP</b>	
Unit 1-4	126
<b>Fergana Valley HPPs</b>	

Cascade/Plant	Installed Capacity (MW)
Shachrichan 5A	11.4
Shachrichan 6A	7.6
UFK 1	2.2
UFK 2	6.7
<b>HPPs in Samarkant region</b>	
Chishrauz	21.9
Irtys	6.4
Taligulyan 1	3
Taligulyan 3	8.8
<b>Hydro plants under the control of Uzsuvenargo</b>	
Andidjan	140
Tuyamuyun	150
Urgut	1.5
Tupolang	30
Achangaran	21
Andidjan	50
<b>Total installed capacity</b>	<b>1,808</b>

Source: CAREC Power Sector Master Plan, ADB. Feb. 2012

## Appendix E: Financial Performance of UE

**Liquidity and operating performance:** The overall financial performance of UE is sound and the operating performance and profitability improved in 2010. The liquidity remains adequate due to some improvements in availability of liquid assets (including cash), relieving pressure on the financing of current expenditures and meeting of short-term obligations. Specifically, availability of cash, marketable securities and receivables to meet short-term obligations improved from 1.16 in 2007 to 1.36 in 2011 as measured by the quick ratio. Nevertheless, the company has significant potential for further improvement of operating efficiency by reducing the receivables estimated at US\$1 billion in 2010 (90 percent of current assets and 100 percent of 2010 revenue). 99 percent are receivables from subsidiaries and associated enterprises and only 1 percent - receivables for electricity and heat supply. This level of receivables substantially reduces availability of cash given the size of assets tied up. The average collection period of total receivables remains quite high at 295 days – substantially above the collection period of good-performing utilities (30-50 days).

Overall, operating performance and profitability improved in 2010. Specifically, the operating profit margin increased from 13.8 percent to 15.4 percent. This was primarily driven by a 35 percent increase of average end-user tariff in 2009-2010.

**Leverage and solvency:** UE has sizeable investment program aimed at expansion and modernization of energy generation, transmission and distribution assets. Substantial part of that investment program was financed through debt from IFIs and domestic financial institutions. Therefore, UE reliance on debt increased. Nevertheless, operating performance is projected to be robust enough to service the debt. As of 2010, the book value of long-term debt (net of current maturities) was around US\$570 million.

The Government plans to increase borrowing for investments and the UE debt is expected to increase. However, the debt-to-equity ratio is projected to remain within reasonable levels with current plans for borrowings. The debt-to-equity ratio was 52:48 in 2010. Debt service coverage ratio remains robust and availability of cash for financing of debt service obligations increased. This increase was due to higher operating cash flow resulting from increased tariffs. The total book value of the long-term borrowing, given the projects approved in 2009-2011, is projected to reach US\$ 1.2 billion by the end of 2012.<sup>87</sup>

### Projected Financial Performance of UE

The long-term financial sustainability of UE will significantly depend on improvement of operational efficiency (increase in power generation efficiency, reductions in losses) and tariff increases. Tariff increases will be required to ensure timely debt servicing and increase the company's ability to finance larger share of investments through its balance sheet. Tariff increases not commensurate with increases in fuel, salary and O&M expenses of the company will result in higher cost of electricity and

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<sup>87</sup> The loans and credits from IFIs are reflected in UE's balance sheet with a lag given the time required for the projects to be ratified and the principal amounts to be on-lent to UE.

diminish the net profit. Appendix Table E.1 provides a summary of the past and forecasted financial performance of UE.

**Appendix Table E.1: Actual and Forecasted Financial Indicators of UE**

	Actual				Forecast			
	2007	2008	2009	2010	2012	2013	2014	2015
<b>Liquidity</b>								
Availability of liquid assets to meet current liabilities	1.16	1.24	1.39	1.36	1.06	1.10	1.19	1.16
Availability of cash to meet current liabilities	0.001	0.001	0.013	0.136	0.129	0.127	0.203	0.112
<b>Financial Risk</b>								
Debt-to-equity	14:86	19:81	29:71	52:48	57:43	58:42	60:40	62:38 <sup>88</sup>
Debt-to-assets	6.5%	8.9%	15.7%	33.7%	36.8%	31.4%	28.6%	29.1%
Debt Service Coverage	74.6	45.1	12.5	8.8	9.6	3.5	3.2	2.5
<b>Operating performance and profitability</b>								
Receivables turnover	3.04	1.96	1.13	1.14	1.30	1.29	1.35	1.40
Average collection period of receivables	120	186	321	295	280	283	270	261
Operating cash flow per unit of revenue	0.03	0.03	0.02	0.06	0.03	0.03	0.03	0.03
Net profit margin	50.6%	40.0%	12.1%	15.9%	15.4%	15.3%	15.4%	15.4%

Source: Bank team estimates based on audited financial statements for 2007-2010, information and data on tariffs, debts, and investment program provided by the Government.

<sup>88</sup> The forecast takes into account only the projects in the Government pipeline.

## Appendix F: Ongoing and Planned Power Sector Projects

Appendix Table F.1: T&D Investments with Secured Funding

Project	Length (km)/Voltage (kV)	Funding Status	Year	Estimated Cost (million US\$)
500 kV overhead line "Talimardjan TPP – TSS Soghdiana" with 500 kV open switch gear at Talimardjan TPP	218 km	Funding secured (World Bank)	2011-2013	153
220 kV "TSS Fazylaman – TSS Lochin"	36 km	Funding secured	2011-2012	9
220 kV overhead line "TSS Kyzyl-Rawat – TSS Yulduz"	30 km	Funding secured	2011-2012	8
220 kV overhead line "TSS Gulcha – TSS Denau"	30 km	Funding secured	2010-2011	6
110 kV overhead line "Andijan HPP – TSS Fazylaman"	10 km	Funding secured	2010-2011	3
220 kV TSS "Ishtihan" including 220 kV overhead line and 110 kV TSS "Gornorudnaya" with 110 kV overhead line	86.4 km	Funding secured	2009-2011	34
Automatic system of electric power control and metering	12,800. control points within the power grids of 6 – 500 kV; 4,5 mln households	Financing secured (World Bank, ADB)	2009-2012	365
500 kV overhead line "Syrdarya TPP – TSS Lochin"	70 km	Funding secured	2011-2012	22

Project	Length (km)/Voltage (kV)	Funding Status	Year	Estimated Cost (million US\$)
220 kV overhead line "Syrdarya TPP – TSS Karakiasay"	71.8 km	Funding secured	2010-2012	9
TSS "Surkhan" including installation of transformer AT-2-220/110 kV	63 MVA	Funding secured	2011-2012	11
110 kV overhead line "HPP-29-TSS Fazylaman" and reconstruction of TSS Fazylaman	2x125 MVA, 7 km	Funding secured	2011-2012	10
110 kV overhead line "L-Sovetabad" and "L-Tashahur"	20 km	Funding secured	2011-2012	4
<b>TOTAL</b>				<b>634</b>

Source: CAREC Power Sector Master Plan, ADB, Feb. 2012 and data provided by the Government during preparation of World Bank financed Talimarjan Transmission Project

**Appendix Table F.2: T&D Investments – Prospective**

Project	Length (km)/Voltage (kV)	Funding Status	Year	Estimated Cost (million US\$)
500 kV overhead line "TSS Syrdarya – TSS Novo-Angren"	130 km	Funding sought (EXIM Bank of China)	2014-2016	93
220 kV overhead line "TSS Uzbekistanskaya TSS Paulgan – TSS Ferghana" (second circuit)	70 km	Funding sought	2012-2014	22
Construction of 500 kV TSS "Namangan" including 500 kV overhead power line TPP – TSS Namangan and cut-in of two single-circuit 220 kV overhead lines at TSS Namangan.	200 km, 32 km	Feasibility study stage	2013-2016	188
220 kV TSS "Kuyu-	2x63 MVA	Feasibility	2011-2012	18

Project	Length (km)/Voltage (kV)	Funding Status	Year	Estimated Cost (million US\$)
Mazar		study stage		
Upgrading of the power grids of 0,4 – 6 – 10 – 35 kV	24926,5 km of power lines, 5731 TS, 43 substations of 35 kV	Feasibility study stage	2010-2015	349
<b>TOTAL</b>				<b>670</b>

Source: CAREC Power Sector Master Plan, ADB, Feb. 2012 and data provided by the Government during preparation of World Bank financed Talimarjan Transmission Project

**Appendix Table F.3: Generation Investments – Under Construction or Funding Secured**

Project	Capacity (MW)	Funding Status	Year	Estimated Cost (Mln. US\$)
Expansion of Talimardjan TPP	900 MW	Under construction	2010-2014	1,280
Navoi TPP (CCGT)	476 MW	Under construction	2009-2012	468
Tashkent TPP (CCGT)	370 MW	Financing secured (JICA)	2009-2014	468
Small HPP “Kamolot”	8 MW	Financing secured	2010-2012	12
Gas booster compressor at Navoi TPP		Financing secured	2011-2012	28
Angren TPP (Heating cycle for high-ash coal firing)	130-150 MW	Financing secured (Gov't of China)	2012-2015	150
Cogeneration at Tashkent TPP	27 MW	Financing secured (NEDO Japan)	2010-2013	57
Expansion generators at Syr Darya and Talimardjan TPPs	20 MW	Financing secured	2010-2012	15
Conversion of Units 1, 2, 3, 4, 5 of Novo-Angren TPP to the all-year coal firing (phase 1)	7 bln kWh p.a.	Financing secured (EXIM Bank of China)	2010-2012	273



Project	Capacity (MW)	Funding Status	Year	Estimated Cost (Mln. US\$)
Upgrading of Charvak HPP	45 MW	Financing secured	2011-2015	50
Upgrading of 220 kV open switchgear at Navoi TPP	483 MW	Financing secured	2011-2012	30
<b>TOTAL</b>				<b>2,831</b>

Source: CAREC Power Sector Master Plan, ADB, Feb. 2012

**Appendix Table F.4: Generation Investments –Prospective and Under Development**

Project	Capacity (MW)	Funding Status	Year	Estimated Cost (Mln. US\$)
Pilot WPP in Tashkent Province	0.75 MW	Financing sought	2011	2
Construction of cooling towers at the Navoi TPP		Prospective project	2013-2015	130
New turbines at Tashkent CHPP	2x27 MW	Prospective project	2013-2015	124
Modernization of 2 units Syrdarinskaya TES	50 MW	Under development	2013-2015	60
Reconstruction of the cooling tower number 1 and 2 Navoi TPP	40 MW	Financing sought	2011-2012	9
Upgrading of Chirchik HPP	Increase of reliability	Financing sought	2013-2015	24
Upgrading of Tashkent HPP	4.5 MW	Financing sought	2012-2015	21
Upgrading of Nijne-Bozsu HPP	2.5 MW	Financing sought	2013-2016	16
Upgrading of Samarkand HPP	Increase of reliability	Financing sought	2013-2015	22
Upgrading of Farkhad HPP	Increase of reliability	Financing sought	2012-2015	32
Upgrading of Kadriya HPP	Increase of reliability	Financing sought	2012-2015	20
Upgrading of Shakhrihan HPP	3.8 MW	Financing sought	2012-2015	6

Project	Capacity (MW)	Funding Status		Year	Estimated Cost (Mln. US\$)
Upgrading of Takhiatash TPP	2x140 MW	Prospective project		2012-2018	331
Conversion of Units 6 & 7 Novo-Angren TPP to coal firing	7.4 bln kWh p.a.	Prospective project		2014-2016	304
Additional generation units to meet incremental demand					3,200
<b>TOTAL</b>					<b>4,300</b>

Source: CAREC Power Sector Master Plan, ADB, Feb. 2012

## Appendix G: Demand Forecasting Methodology

The methodology is based on an equation expressing the relationship between power demand growth, real income growth, and growth in real electricity prices. The rate of demand growth is assumed to be equal to the rate of growth of real electricity prices times the price elasticity, plus the rate of growth of income times the income elasticity. This is expressed formally as:

$$d = p \cdot b + g \cdot a$$

where:

$d$  = annual average rate of growth of demand

$a$  = income elasticity (positive)

$g$  = growth of real income between successive forecast periods

$b$  = price elasticity of demand (negative)

$p$  = change of real power prices between successive forecast periods.

The forecast period is the calendar year, beginning in 2011 and extending to 2031. High, low and base cases were developed using different assumptions about GDP growth, price growth, and income elasticity of demand.

**Appendix Table G.1: Demand Growth Assumption**

Demand Case	Assumption about GDP growth	Assumption about income elasticity of demand	Assumptions about price growth
Base	2011-2012: 7.0% 2013-2014: 6.5% 2015: 6% 2016-2031: 5%	0.8	2011: 5.0% 2012-2021: 5.5% 2022-2031: 2.0%
Low	2011-2012: 5.5% 2013-2014: 5.0% 2015: 4.5% 2016-2031: 3.5%	0.8	2011: 5.0% 2012-2021: 5.5% 2022-2031: 2.0%
High	2011-2012: 8.0% 2013-2014: 7.5% 2015: 7.0% 2016-2031: 6.0%	-.8	2011: 5.0% 2012-2021: 5.5% 2022-2031: 2.0%

A constant price elasticity of electricity demand equal to -0.20 is assumed when the average electricity tariff level across consumer tariff groups is changed. A higher price elasticity of demand, -0.50, is assumed for the reduction in consumption due to reduction in non-technical losses (mainly for unpaid consumption by households).

**Technical losses** (TL<sub>*n*</sub> in year *n*) on electricity generated in Uzbekistan are projected separately as a percent of net energy transmitted (energy generated *plus* imports

less exports) in each year  $n$ . The model assumes that technical losses are reduced from the actual level of 17 percent of net electricity demand (consumption) in 2011 to 11 percent in 2023.

**Non-technical losses** in year  $n$  ( $NTL_n$ ) are assumed to be reduced from 7 percent to 5 percent by 2019.

The tables below summarize the demand forecasts for the base, low and high cases.

**Appendix Table G.2: Base Case Demand Forecast**

	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Growth of GDP	(%)	6.50	6.50	6.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Income elasticity of demand	-	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Estimated tariff growth	(%)	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Price elasticity of demand	-	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Net electricity demand incl. unserved energy	GWh	45,402	47,263	49,012	50,433	51,896	53,401	54,949	56,543	58,182	60,277	62,447	64,695	67,024	69,437	71,937	74,526	77,209
Growth rate net demand	(%)	4.10%	4.10%	3.70%	2.90%	2.90%	2.90%	2.90%	2.90%	2.90%	3.60%	3.60%	3.60%	3.60%	3.60%	3.60%	3.60%	3.60%
Commercial losses	(%)	6.60	6.30	6.00	5.70	5.40	5.10	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Commercial losses transferred to demand	GWh	136	213	294	378	467	561	604	622	640	663	687	712	737	764	791	820	849
Consumer demand before technical losses	GWh	48,534	50,453	52,247	53,686	55,165	56,685	58,301	59,992	61,732	63,954	66,256	68,642	71,113	73,673	76,325	79,073	81,919
Technical losses	(%)	16.00%	15.50%	15.00%	14.50%	14.00%	13.50%	13.00%	12.50%	12.00%	11.50%	11.00%	11.00%	11.00%	11.00%	11.00%	11.00%	11.00%
Technical losses	GWh	7,264	7,326	7,352	7,313	7,265	7,209	7,143	7,068	6,982	6,932	6,869	7,116	7,373	7,638	7,913	8,198	8,493
Electricity sent out to power system	GWh	55,798	57,779	59,598	60,999	62,430	63,894	65,445	67,060	68,714	70,886	73,125	75,758	78,485	81,311	84,238	87,271	90,412
Growth rate of electricity sent out	%	3.55%	3.55%	3.15%	2.35%	2.35%	2.34%	2.43%	2.47%	2.47%	3.16%	3.16%	3.60%	3.60%	3.60%	3.60%	3.60%	3.60%
Load factor	%	68.00%	67.50%	67.00%	66.50%	66.00%	65.50%	65.00%	65.00%	65.00%	65.00%	65.00%	65.00%	65.00%	65.00%	65.00%	65.00%	65.00%
Peak load	MW	9,367	9,772	10,154	10,471	10,798	11,136	11,494	11,777	12,068	12,449	12,843	13,305	13,784	14,280	14,794	15,327	15,879

**Appendix Table G.3: Low Case Demand Forecast**

	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Growth of GDP	(%)	5.00	5.00	4.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50	3.50
Income elasticity of demand	-	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Estimated tariff growth	(%)	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Price elasticity of demand	-	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Net electricity demand incl. unserved energy	GWh	43,896	45,169	46,299	47,086	47,886	48,700	49,528	50,370	51,226	52,456	53,715	55,004	56,324	57,676	59,060	60,477	61,929
Growth rate net demand	(%)	2.90%	2.90%	2.50%	1.70%	1.70%	1.70%	1.70%	1.70%	1.70%	2.40%	2.40%	2.40%	2.40%	2.40%	2.40%	2.40%	2.40%
Commercial losses	(%)	6.60	6.30	6.00	5.70	5.40	5.10	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Commercial losses transferred to demand	GWh	132	203	278	353	431	511	545	554	563	577	591	605	620	634	650	665	681
Consumer demand before technical losses	GWh	46,925	48,218	49,354	50,123	50,903	51,695	52,549	53,443	54,351	55,656	56,991	58,359	59,760	61,194	62,663	64,166	65,706
Technical losses	(%)	16.00%	15.50%	15.00%	14.50%	14.00%	13.50%	13.00%	12.50%	12.00%	11.50%	11.00%	11.00%	11.00%	11.00%	11.00%	11.00%	11.00%
Technical losses	GWh	7,023	7,001	6,945	6,827	6,704	6,575	6,439	6,296	6,147	6,032	5,909	6,050	6,196	6,344	6,497	6,653	6,812
Electricity sent out to power system	GWh	53,949	55,220	56,299	56,950	57,607	58,270	58,988	59,739	60,498	61,688	62,900	64,410	65,955	67,538	69,159	70,819	72,519
Growth rate electricity sent out	%	2.36%	2.36%	1.96%	1.16%	1.15%	1.15%	1.23%	1.27%	1.27%	1.97%	1.96%	2.40%	2.40%	2.40%	2.40%	2.40%	2.40%
Load factor	%	68.00	67.50	67.00	66.50	66.00	65.50	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00
Peak load	MW	9,057	9,339	9,592	9,776	9,964	10,155	10,360	10,492	10,625	10,834	11,047	11,312	11,583	11,861	12,146	12,437	12,736

**Appendix Table G.4: High Case Demand Forecast**

	Unit	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029
Growth of GDP	(%)	7.50	7.50	7.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00
Income elasticity of demand	-	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
Estimated tariff growth	(%)	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	5.50	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Price elasticity of demand	-	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Net electricity demand incl. unserved energy	GWh	46,497	48,776	50,971	52,857	54,812	56,840	58,943	61,124	63,386	66,175	69,087	72,126	75,300	78,613	82,072	85,683	89,453
Growth rate net demand	(%)	4.90	4.90	4.50	3.70	3.70	3.70	3.70	3.70	3.70	4.40	4.40	4.40	4.40	4.40	4.40	4.40	4.40
Commercial losses	(%)	6.60	6.30	6.00	5.70	5.40	5.10	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Commercial losses transferred to demand	GWh	139	219	306	396	493	597	648	672	697	728	760	793	828	865	903	943	984
Consumer demand before technical losses	GWh	49,706	52,068	54,335	56,266	58,265	60,336	62,539	64,853	67,252	70,212	73,301	76,526	79,893	83,409	87,079	90,910	94,910
Technical losses	(%)	16.00%	15.50%	15.00%	14.50%	14.00%	13.50%	13.00%	12.50%	12.00%	11.50%	11.00%	11.00%	11.00%	11.00%	11.00%	11.00%	11.00%
Technical losses	GWh	7,440	7,560	7,646	7,664	7,674	7,673	7,663	7,641	7,606	7,610	7,600	7,934	8,283	8,647	9,028	9,425	9,840
Electricity sent out to power system	GWh	57,145	59,628	61,980	63,930	65,939	68,009	70,202	72,493	74,859	77,822	80,900	84,460	88,176	92,056	96,107	100,335	104,750
Growth rate electricity sent out	%	4.35%	4.35%	3.94%	3.15%	3.14%	3.14%	3.22%	3.26%	3.26%	3.96%	3.96%	4.40%	4.40%	4.40%	4.40%	4.40%	4.40%
Load factor	%	68.00	67.50	67.00	66.50	66.00	65.50	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00	65.00
Peak load	MW	9,593	10,084	10,560	10,974	11,405	11,853	12,329	12,732	13,147	13,667	14,208	14,833	15,486	16,167	16,879	17,621	18,397

## **Appendix H: Comparing the Costs of Generation**

Going forward, the Government will need to make decisions on type of new generation to add considering a range of economic, social and other factors, including the priority of substantially increasing gas exports and diversifying electricity generation mix. To that end the Government needs to consider investments in generation capacity, which uses fuels other than gas. Gas must be compared to other fuels in economic terms, including the negative externalities (principally, local and global pollution) associated with natural gas and other fossil-fuels.

### **Economics of power generation options**

Estimates of the levelized energy costs of electricity generated with a number of technologies are provided in Appendix Table H.1. The costs of CO<sub>2</sub> are included.



**Appendix Table H.1: Cost of Potential Power Generation Options (including CO<sub>2</sub> costs)**

	Plant size (MW)	Capacity factor	Annual generation (GWh/yr)	Capital cost (US\$/kW)	Non-Fuel Fixed O&M (US\$/kW-yr)	Non-Fuel Variable O&M (US\$/MWh)	Fuel Cost (US\$/MWh)	Carbon Content (kg/MWh)	Levelized Energy Cost (US\$/MWh)
Natural Gas CCGT	1,000	90%	7,884	1,422	7	5	50.08	360	83
Coal (Lignite)	1,000	90%	7,884	2,200	20	6	12.8	1,020	73
Biomass steam turbine	20	85%	149	3,700	0	27	19	0.00*	100
Small hydro	2	40%	9	2,500	0	20	0	0.00	100
Wind	100	25%	219	2,500	0	15	0	0.00	150
Solar thermal (central station)	100	34%	298	4,600	0	30	0	0.00	190
Solar PV	50	25%	110	4,000	0	30	0	0.00	270

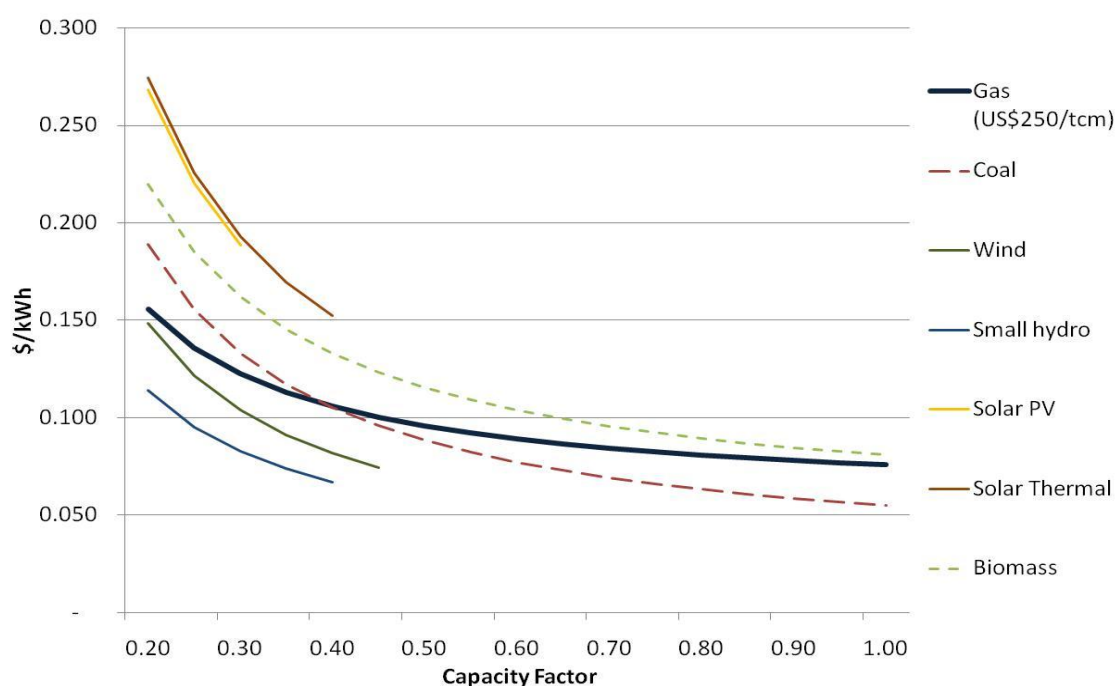
Source: World Bank team based on data from CAREC Power Sector Master Plan, ADB, Feb. 2012; International Energy Agency (IEA) and OECD Nuclear Energy Agency (NEA).

\*Note: Biomass is assumed to have zero net carbon emissions. If wood from forests or dedicated energy crops was used for fuel, this assumption would need to be revisited and potentially changed.

The analysis above is based on relatively conservative assumptions for the capacity factors and costs of renewable energy technologies. These assumptions are based on International Energy Administration estimates or, in some cases, estimates provided by UE. Appendix Figure H.1 provides comparison of costs of renewable and fossil fuel generation options exclusive of cost of greenhouse gas emissions. Appendix Figure H.2 provides the same comparison, inclusive of cost of greenhouse gas emissions for coal- and gas-fired generation.

It is important to note that these figures only compare resources on a levelized energy cost basis and do not account for the fact that not all renewable energy resources can serve as baseload generation.<sup>89</sup> Wind and solar plants have intermittent and diurnal and seasonal variations in output. As a result, they cannot serve as baseload generating resources. Biomass plants are typically baseload and small hydropower plants do not have the intermittency problems of wind and solar.

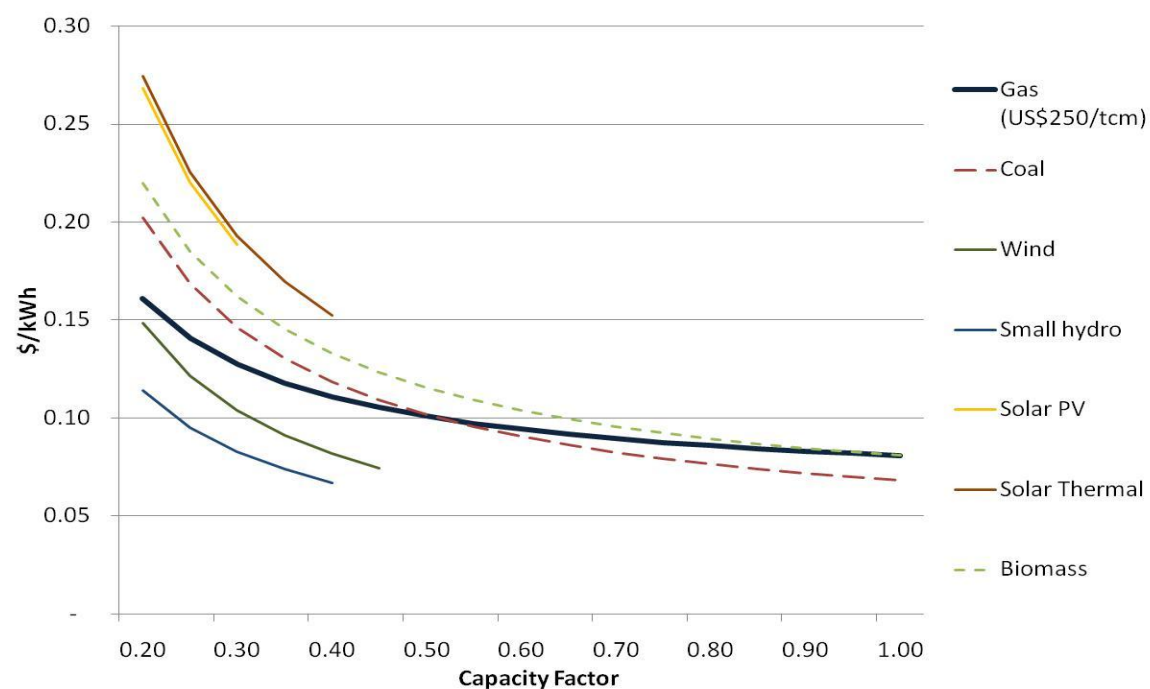
**Appendix Figure H.1: Comparing the Costs of Renewable Energy and Fossil Fuel Technologies, excluding CO<sub>2</sub>**



Source: World Bank team based on data from International Energy Agency (IEA) and OECD Nuclear Energy Agency (NEA), "Projected Costs of Generating Electricity," 2010 Edition

<sup>89</sup> The costs of intermittency or non-dispatchability of renewable energy generation can be included in LECs through a "capacity penalty".

**Appendix Figure H.2: Comparing the Costs of Renewable Energy and Fossil Fuel Technologies, including CO<sub>2</sub>**



Source: World Bank team based on data from International Energy Agency (IEA) and OECD Nuclear Energy Agency (NEA), "Projected Costs of Generating Electricity," 2010 Edition

Note: Biomass is assumed to have zero net carbon emissions