A WORLD BANK STUDY

Tajikistan's Winter Energy Crisis

ELECTRICITY SUPPLY AND DEMAND ALTERNATIVES

Daryl Fields, Artur Kochnakyan,
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CAEWDP
Central Asia Energy-Water Development Program

THE WORLD BANK
Washington, D.C.

UKaid
from the British people

ESMAP
Energy Sector Management Assistance Program

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Contents

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Appendixes

Boxes

Figures

Map

http://dx.doi.org/10.1596/978-0-8213-9967-5

Tables

http://dx.doi.org/10.1596/978-0-8213-9967-5

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Abbreviations

ADB	Asian Development Bank
bcm	billion cubic meters
CAEWDP	Central Asia Energy-Water Development Program
CAPS	Central Asia Power System
CAREC	Central Asia Regional Economic Cooperation
CASA	Central Asia—South Asia (Transmission Line)
CCGT	Combined-Cycle Gas Turbine
CFL	compact fluorescent lamp
CHP	Combined Heat and Power Plant
CIS	Commonwealth of Independent States
CNPC	China National Petroleum Corporation
DFID	Department for International Development
DH	District Heating
DSM	Demand-Side Management
ECA	Europe and Central Asia
EE	energy efficiency
EEP	Energy Efficiency Program
ENTSO-E	European Network of Transmission System Operators For Electricity
EU	European Union
GDP	gross domestic product
GoT	Government of Tajikistan
GT	Gas Turbine
GWh	gigawatt hour
HPP	hydropower plant
HV AC/DC	high-voltage alternating current/direct current
IFI	international financial institution
kgoe	kilogram of oil equivalent
kv	kilovolts

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kWh	kilowatt hour
LOC	letter of credit
LRAIC	long-run average incremental cost
MW	megawatt
NEPS	North East Power System (Afghanistan)
NGO	nongovernmental organization
NPV	net present value
PPA	Power Purchase Agreement
PV	photovoltaic (solar power)
RE	renewable energy
RECCA	Regional Economic Cooperation Conference on Afghanistan
ROR	run-of-river
RRS	Region of Republican Subordination
SEA	Strategic Environment Assessment
SHPP	small hydropower promotion project
STO	Solar Thermal Option
T&D	transmission and distribution
TALCO	Tajik Aluminum Company
TCF	thousand cubic feet
TCM	trillions of cubic meters
TPP	thermal power plant
TUTAP	Turkmenistan, Uzbekistan, Tajikistan, Afghanistan, and Pakistan (Transmission Line)
TWh	terawatt hour
UES	United Electricity System
UHS	Urban Household Strategy
USGS	United States Geological Survey
USSR	Union of Soviet Socialist Republics
WTP	willingness to pay

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Executive Summary

Tajikistan's electricity system is in a state of crisis. Approximately 70 percent of the Tajik people suffer from extensive shortages of electricity during the winter. These shortages, estimated at about 2,700 GWh, about a quarter of winter electricity demand, impose economic losses estimated at over US$200 million per annum or 3 percent of gross domestic product (GDP). In addition to the financial costs of inadequate electricity, the Tajik people suffer the social costs as well, including indoor air pollution from burning wood and coal in homes and health impacts from extreme winters. The electricity shortages increased considerably in 2009 when Tajikistan's energy trade with neighboring countries through the Central Asia Power System (CAPS) stopped; combined with continued aging of Tajikistan's power generation assets, the situation has become worse. The electricity shortages have not been addressed because investments have not been made in new electricity supply capacity and maintenance of existing assets has not improved. The financial incentive for electricity consumers to reduce their consumption is inadequate as electricity prices are among the lowest in the world.

Without prompt action to remedy the causes of Tajikistan's electricity crisis and with growing demand, the shortages could increase to about 4,500 GWh by 2016 (over a third of winter electricity demand) or worse. Barki Tajik, the state power utility company, has kept Tajikistan's power system functioning under difficult circumstances, but the system is increasingly vulnerable to a major breakdown that would jeopardize the supply of electricity to all customers and cause enormous damage to Tajikistan's economy.

The Government of Tajikistan recognizes both the importance and challenges of energy security and has therefore introduced various measures to help meet demand. President Emomalii Rahmon's annual message to the Majlisi Oli (Parliament) of the Republic of Tajikistan (April 20, 2012) underscored the importance of energy saving policies, effective energy resources management and development, reductions of energy losses, and ongoing exploration of new energy supplies.

The World Bank undertook this study to assist the Government of Tajikistan (GoT) in finding ways to overcome the current electricity shortages and establish a sound basis for meeting the growing electricity demand in Tajikistan. The study focuses on the investments and policy reforms needed between now and

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2020 to strengthen the financial, technical and institutional capacity of the Tajik power sector and prepare the GoT for undertaking a major expansion of power supply capacity. The study explores a range of supply and demand alternatives (for example, thermal, run-of-river hydro, other renewables, energy efficiency, demand management). The study excludes large hydropower plants with storage, given their complexity and global experience that such projects are subject to delays. The study does not include the proposed Rogun hydropower project, which is currently the subject of comprehensive studies to determine costs and economic, technical, environmental and social viability. However, the study presents actions of highest urgency in the next four to five years to address the country's winter energy crisis and establish a base for long-term energy security.

The winter electricity shortages are caused by a combination of low hydropower output during winter when river flows are low and high demand driven by heating needs. Most of the run-of-river hydropower projects, as currently designed, are expensive sources of energy and provide limited winter energy. Originally part of an operating regime for Central Asia without national borders, the existing set of projects are designed with installed capacity in excess of the available winter flows. Within the context of Tajikistan's current operating regime, this increases the cost of winter supply and exacerbates the problem of summer surplus. Designs of the identified projects (in particular nonstorage projects) need to be revised to better focus on domestic needs and current regional opportunities and constraints. Projects that are situated on the Pyanj River will require coordination with Afghanistan, which adds an element of uncertainty about timing for these projects. New run-of-river hydropower capacity, therefore, is not expected to play an important role in meeting the power system needs before 2020.

Rebuilding regional power trade could provide substantial and affordable relief for Tajikistan's winter power shortages and benefit neighboring countries. The collapse of electricity trade through the CAPS was a critical contributing factor that led to Tajikistan's electricity crisis. Trust among neighboring countries has been lost and will take time to reestablish. However, efforts to rejuvenate trade are important for energy stability in Tajikistan and to reap the enormous potential benefits for all countries in Central Asia (estimated to be more than US$2 billion with limited incremental costs). Few nonhydropower renewable energy options have been identified to date. This leaves energy efficiency, thermal power, and fuel switching as the only other options for Tajikistan other than restoring energy trade.

The GoT should focus its immediate attention on three ways to eliminate the current winter power shortages: (1) ambitious energy efficiency plans to reduce uneconomic power usage; (2) new dual-fired thermal power supply to complement the existing hydropower supply during winter; and (3) increased energy imports to leverage surplus electricity supply in neighboring countries. A strategy that combines these solutions could nearly eliminate the winter energy shortages by 2016, but the achievement of these goals requires accelerated, focused

Tajikistan's Winter Energy Crisis: Electricity Supply and Demand Alternatives
http://dx.doi.org/10.1596/978-0-8213-9967-5

commitment by the GoT and support from its partners. A package of policy reforms, trade promotion, and investments is needed. Measures to manage demand, switch fuels for winter heating, and reduce losses would be the most significant and immediate contributors to solving the problem, covering about 40 percent of the expected deficit in 2016. These must be matched with new supply and imports (about 24 percent and 37 percent, respectively).

Measures to Reduce Domestic Demand

An ambitious energy efficiency program (EEP) should be broad based and address the industrial sector buildings and scale up the power network loss reduction program, as well as align electricity tariffs. An EEP could save roughly 1,635 GWh of energy in the winter months by 2016. Experience in the industrial sector of other countries has shown that when energy prices are set to reflect the full cost of supply, industries are privately owned, and barriers to competition are largely eliminated, the private sector responds quickly to improve efficiency. An assessment of energy use and conservation at Tajikistan's state-owned aluminum company, Tajik Aluminum Company (TALCO), is being conducted by consultants financed by the World Bank. That energy study provides evidence of prospects for energy efficiency investments that could save 1,180 GWh per year and show a payback period of 2½ years on average. Such investments would decrease the energy deficit in the six winter months by about 420 GWh (by 2016) and could enable increased energy storage in the Nurek reservoir for use in the winter. These investments would contribute significantly to eliminating the existing winter energy shortages as well as improving the commercial viability of TALCO. If TALCO switched the maintenance of their plant and equipment from summer (current practice) to winter, the investments in energy efficiency could be implemented as part of regularly scheduled maintenance cycles in about three to four years while also reducing winter energy consumption by an additional 150 GWh.

Experience in other countries has shown investments in building energy efficiency can achieve energy savings of 20 percent with modest investments; 50 percent savings can be achieved with a comprehensive energy efficiency investment plan. Energy efficiency measures generally cost less than 5 cents per kWh and are, for the most part, the least cost approach to addressing the supply-demand gap. Modest investments in building insulation and reduction of air leakage can contribute significant gains to energy efficiency. Given that many customers' incomes are limited, an EEP should initially focus on low-cost, high-impact investments. The three key elements of the program would be as follows: (1) establish the incentives for customers to ration their use of energy through higher electricity prices; (2) provide low-cost financing for energy audits and energy efficiency investments; and (3) provide support through information sharing on energy efficiency. Financing for such a program could be provided through a combination of donor funding, climate funds, and customers' own resources.

Tajikistan's Winter Energy Crisis: Electricity Supply and Demand Alternatives
http://dx.doi.org/10.1596/978-0-8213-9967-5

Energy losses in the Tajik power transmission and distribution networks are nearly double the level of good practice and should be an important part of the EEP. With financial support from the World Bank, the GoT has started its network loss reduction program but improvements to date are modest. It is recommended that this program be accelerated with a target of reducing electricity network losses from the current level of 18 percent to 12 percent by 2020, with an interim target of 15 percent by 2016.

Measures to Increase Domestic Supply

Between now and 2020, rehabilitation of the existing hydropower assets is an important component of the plan to address Tajikistan's winter electricity crisis. Many of the hydropower assets are operating well beyond their design life. They have remained operational through stopgap measures by the power sector staff using budgets well below industry standards, leaving the power system at risk to catastrophic system failure, unless it receives proper maintenance soon, and is forgoing technological upgrades that could increase capacity. It is recommended that priority investments are reviewed so that rehabilitation can be undertaken to upgrade the capability of the existing plants and provide more electricity per unit of water. Although the cost of rehabilitation is estimated at more than US$1 billion, it is expected to be among the most cost-effective investment in securing electricity supply as it could avoid a systemwide power system collapse in the medium term.

The GoT should fast-track the implementation of the proposed thermal power plant. The plant could initially use low-cost local coal to bring new domestic sources of thermal power to the electricity system. The plant could provide 1,000 GWh per year operating base loaded during the winter and partially during the months immediately before winter seasons when hydropower does not fully meet demand. In addition, given the possibility of local natural gas supply, and/or the reestablishing of gas supply from Uzbekistan or Turkmenistan, the GoT should consider that the plant be designed to be dual fired (coal and gas). This fuel flexibility would make it possible to use clean, low-cost local gas in the future at modest incremental investment cost.

The GoT should also consider increasing the use of waste heat to heat buildings. The proposed thermal power could be designed as a combined heat and power plant (CHP) so that the waste heat from the plant could be used to heat homes in Dushanbe during the winter. Waste heat from TALCO could also be used to heat the buildings in the adjacent town. An investment in waste heat could be realized in four years and has been managed well in many other countries in the Europe and Central Asia region.

Measures to Increase Regional Electricity Trade

Electricity imports could be increased to 400–1,550 GWh during the winter months. In the near term, these imports could come from Uzbekistan. However,

http://dx.doi.org/10.1596/978-0-8213-9967-5

this option may not be available in the medium term if Uzbekistan runs into an electricity supply shortfall relative to its own demand. Because the Tajik power system is severely energy constrained, the available off-peak power from Uzbekistan could help reduce Tajikistan's winter energy shortfall, firm up capacity at Nurek hydropower plant, and provide scope for using flexible arrangements for electricity supply from Uzbekistan. For example, once the Uzbek supply-demand balance tightens, the standard arrangement for importing electricity from Uzbekistan may need to be replaced by a swap arrangement in which Turkmenistan supplies power to Uzbekistan with Uzbekistan supplying a similar amount of electricity to Tajikistan, in addition to new transmission linkages directly with Turkmenistan.

Issues to Be Addressed

The program outlined above is ambitious, but the electricity situation in Tajikistan is dire. Given the economic and social costs of the electricity crisis in Tajikistan, the primary concern of the World Bank is to help the GoT solve its winter energy shortages in the most sustainable ways possible. The proposed plans would require significant commitment, management, and financing. It is evident that the Tajik power sector cannot finance these investments under the current electricity prices. The following are some of the key issues that will need to be addressed:

1. **The proposed plan would require US$3.4 billion over the next eight years, roughly US$380 million per year or about 5 percent of GDP**. A program of this size would require broad-based support from a number of Tajikistan's partners: International Financial Institution (IFIs), donors, neighboring countries, and the private sector. The GoT should prepare and commit to implementation of a specific program, including actions that they will take, and solicit broad-based support from its partners.
2. **With the current low electricity prices, this plan to address Tajikistan's electricity crisis is not financially viable; electricity prices would need to increase by roughly 50 percent[1] in the short term.** It is expected that a price increase of this size is needed as soon as possible to (1) dampen growth in demand by providing an incentive to use energy prudently; and (2) help fund part of the cost of the investment program. A delay in price increases would delay the closing of the supply-demand gap, resulting in extending the costs associated with load shedding. Such a price increase would be roughly one third of the estimated future cost of supply and below the estimated willingness to pay for most consumers. The resulting electricity price would be well below the level of electricity prices in other countries in the region. The exact size of the required price increase should be determined from a detailed financial analysis coupled with a prioritization of investments in the power sector and social safety nets to protect the poor.
3. **A targeted social safety net should be developed to address the needs of the poor and economically vulnerable electricity consumers.** It is recommended that the GoT establish a targeted safety net for the poor, coupled

http://dx.doi.org/10.1596/978-0-8213-9967-5

with a household EEP to decrease household energy consumption while maintaining healthy living standards. The economic payback for implementing EEPs for housing for the poor has often been found to have high returns as the buildings are typically highly energy inefficient.

4. **The increase in pollution and associated health and climate risks from new coal-fired power as well as imported natural gas-fired power plants would need to be minimized**. Domestic thermal power supply is clearly needed to help balance the variability of the hydropower resources and provide electricity to the Tajik people throughout the year. Investing in dual firing capability in coal-fired plants should be a priority to allow substitution of coal with cleaner natural gas as soon as it becomes available.
5. **Rebuilding trust and removing political barriers to electricity trade would benefit all Central Asian countries**. Restoration of a synchronous tie is likely to enable considerable benefits not only to Tajikistan, but its neighboring countries as well, and so represents an important goal for all countries in Central Asia. This could be achieved while Uzbekistan still has excess power capacity. More immediately, reducing trade barriers to facilitate transit of electricity through Uzbekistan through swap or other arrangements should also be pursued to enable existing import agreements between Turkmenistan and Tajikistan. Rebuilding trust would require (1) carefully constructed contracts in the short term; and (2) development of new market mechanisms and protocols for interconnection to support long-term energy trade.

Note

1. The proposed 50 percent price increase is in real terms and should thus be added to local inflation levels.

Tajikistan's Winter Energy Crisis: Electricity Supply and Demand Alternatives
http://dx.doi.org/10.1596/978-0-8213-9967-5

CHAPTER 1

Purpose of the Study

Reliable power supply is critical for Tajikistan's economy and poverty reduction goals. Without reliable, affordable electricity throughout the year, Tajikistan's businesses cannot invest, operate, and create jobs; hospitals and schools cannot function fully or safely with frequent power cuts during winter; citizens suffer indoor air pollution from burning wood for heating and cooking. Electricity also powers the country's two largest exports: aluminum and agricultural produce, which account for about 30 percent of Tajikistan's annual gross domestic product and almost 45 percent of export earnings. Currently, electricity is the cheapest available resource to heat homes so the residential and commercial sectors are highly dependent on electricity for heat as well as lighting and industrial processes. The government is responsible for guiding programs that keep power supply apace with demand.

The Government of Tajikistan (GoT) recognizes the importance and challenge of energy security and has introduced various measures to help meet demand. President Emomalii Rahmon's annual message to the Majlisi Oli (Parliament) of the Republic of Tajikistan (April 20, 2012) underscored the importance of energy saving policies, effective energy resources management and development, reduction of energy loss, and ongoing exploration for new energy supplies.

The purpose of this study is to assist the government in further defining ways to meet growing demand for electricity in Tajikistan, with a particular focus on the recurring winter shortages which amount to about 24 percent of winter demand. The study also examines the potential benefits of power exports, particularly during summers when hydropower plants spill energy. The study explores a range of alternatives to meet electricity demand as quickly as possible and develop a short-term plan of action to alleviate the social and economic costs of winter shortages. The study focuses on multiple initiatives that can be started immediately and simultaneously, and will establish fundamental components of energy security for Tajikistan, namely to moderate unsustainable demand growth, protect the current asset base, and remedy the thermal/hydro imbalance in the energy sector.

http://dx.doi.org/10.1596/978-0-8213-9967-5

The study excludes hydropower projects with large (seasonal) storage. The major project proposed by the GoT in this category is the Rogun hydropower project on the Vakhsh River cascade, which is currently under study. Given the ongoing status of the Rogun assessment studies and global experience that demonstrates that such large and complex hydropower projects, even if they are deemed technically and economically feasible, are subject to long periods of preparation and delays, proposed projects with seasonal water storage are not included in this study. However, the study recommendations are relevant regardless, and the World Bank considers the actions proposed in this report to be of highest urgency in the next four to five years to realize the country's short- and long-term energy security.

The study examines alternative investments to both manage demand and expand supply for electricity in the period to 2020. Demand management includes energy efficiency and fuel switching opportunities. New supply of electricity explores the full range of alternatives, including run-of-river hydropower projects without storage, thermal resources (e.g., coal, natural gas), other renewable energy, and imports. The study relies on existing information and project descriptions, with independent checks and verifications. A full reassessment of resources and projects lies outside the scope of the study, although comments and suggestions are offered for future research. The methodology used to analyze the development priorities is outlined in appendix A.

This report is structured as follows. Chapter 2 outlines the market for electricity and explores opportunities for energy efficiency and demand management. Chapter 3 describes the alternative sources of supply. Chapter 4 turns to the immediate challenge of eliminating winter energy shortages that recur annually, outlining a package of actions and investments, as well as risks and constraints. Chapter 5 explores how new approaches can reduce overall costs, increase reliability, and strengthen the base for long-term energy security. Chapter 6 summarizes specific actions for priority attention.

Tajikistan's Winter Energy Crisis: Electricity Supply and Demand Alternatives
http://dx.doi.org/10.1596/978-0-8213-9967-5

CHAPTER 2

The Tajik Market for Electricity

The basis for any power sector investment plan is the demand for energy services. This chapter describes the current and future demand for electricity in the sections entitled "The Evolving Energy Market in Tajikistan" and "Current Demand for Electricity," respectively. Future demand takes into consideration income growth, economically efficient price signals (e.g., tariff increases), and various energy efficiency measures. The chapter concludes with an examination of the export opportunities as a secondary source of demand for energy investments in the section entitled "Demand Projections."

The Evolving Energy Market in Tajikistan

The Central Asia Power System (CAPS) was developed in the 1970s and covered five former USSR republics: Southern Kazakhstan,[1] the Kyrgyz Republic, Tajikistan, Turkmenistan, and Uzbekistan. The planning process for this system did not view them as five independent states; borders between states were disregarded. As a result, generation units serviced markets on either side of the borders as if the borders did not exist. Both the planning and operation of this system was optimized to meet the needs of the region and reduce the overall cost of supply. The CAPS system had sufficient generation and transmission resources to fully meet its needs.

Following the collapse of the USSR, the design, operation, and maintenance of CAPS gradually collapsed. Each country sought to achieve energy independence in terms of generation capacity and fuel supply. The differences in the resource base for each country meant that the systems became unbalanced. Countries with significant hydropower resources and limited fossil fuels, like Tajikistan and the Kyrgyz Republic, started to discharge more energy in the winter months as customers gravitated to using low-cost electricity to heat their homes. This created problems with both winter and summer operation, resulting in system operation in which regional optimization was no longer a goal. Significant disagreements among countries resulted.

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Power system operation was further complicated by irrigation needs that had an impact on hydropower use. Bilateral arrangements between Central Asian countries became a complex set of agreements that included water, fossil fuels, and electricity. The complexity of these arrangements led to disagreements over water releases, particularly in the Syr Darya Basin, which then had an impact on electricity trade and unilateral adjustments on the price and availability of fossil fuels. Such disagreements created political, social, and economic difficulties within the whole Central Asia region, reinforcing the notion of energy self-sufficiency within each country.

During 2008/09, two major developments exacerbated these problems. First, Tajikistan constructed a North-South 500-kilovolt line connecting its previously separated northern and southern regions. This rendered large power flows through Uzbekistan unnecessary. Second, South Kazakhstan and North Kazakhstan systems were interconnected through a 500-kilovolt transmission. In the context of an unusually cold winter it was reported that Tajikistan, the Kyrgyz Republic, and Uzbekistan drew excessive power from the regional grid far beyond what they were entitled to draw, jeopardizing the stability of the North-South 500-kilovolt Kazakh link and creating serious supply shortages in South Kazakhstan.[2] Kazakhstan immediately withdrew from CAPS, followed by Uzbekistan to avoid system stability problems.[3] Subsequently, Kazakhstan, the Kyrgyz Republic, and Uzbekistan rejoined CAPS, largely due to the intricate water-energy linkages in the Syr Darya basin and the interwoven nature of the Kyrgyz Republic and Uzbekistan systems. Tajikistan, however, became fully isolated from CAPS and its energy imports from both CAPS and Turkmenistan came to an end (details can be found in appendix B).

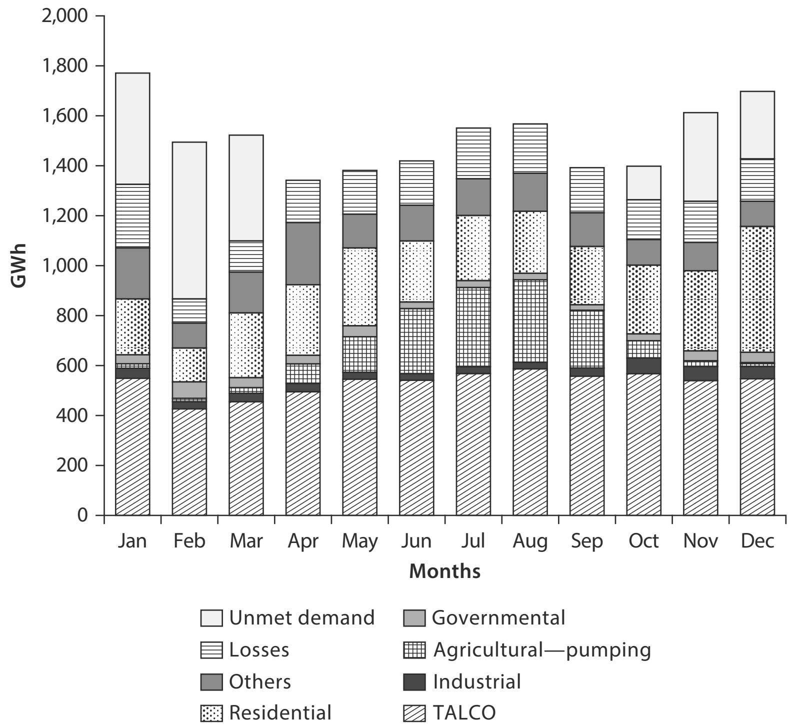
Current Demand for Electricity

Over the last decade, Tajikistan had an annual electricity demand of between 16,000 and 17,000 GWh, reaching its maximum in 2007. In the wake of the economic crisis, demand declined to a level just above 16,000 GWh. The aluminum smelter TALCO accounts for 40 percent of demand. The second largest customer group is the residential sector at 44 percent.

Electricity demand varies considerably over the year, which is common for countries with extreme temperatures during winter or summer. Although TALCO's demand is relatively constant, the demand of residential, government, and commercial ("other") customers is highest in winter when low temperatures and short daylight periods increase the demand for heating and lighting. Compared with other countries in the Europe and Central Asia (ECA) Region where residential heating relies on natural gas or district heating, demand for electricity is unusually high in Tajikistan because electricity prices are low and there are limited options for heating. The electricity demand of the agricultural sector is largely restricted to the summer months when water-intensive crops such as cotton require irrigation. The structure and seasonality of demand over the year 2009 is shown in figure 2.1.

Tajikistan's Winter Energy Crisis: Electricity Supply and Demand Alternatives
http://dx.doi.org/10.1596/978-0-8213-9967-5

Figure 2.1 Monthly Electricity Demand by Sector, 2009



Source: SNC 2011.

Tajikistan's power system cannot currently meet demand, leading to significant shortages in winter months. These shortages are due to a combination of high demand for heating in winter, loss of imports of electricity and gas since 2009, and dependency on a hydropower system with diminished capacity in the winter due to low river flows. Winter demand[4] coincides with the minimum availability of electricity generation from hydropower plants, due to hydrological conditions. Specifically, river flows are at their lowest in March, reducing output at all power plants, especially those without storage capability (that is, "run-of-river" plants). Figure 2.2 compares electricity generation for the four different years with total demand for 2009; the gap between the solid and dotted lines represents unmet demand (also shown in figure 2.1).

The unmet (or "unserved") demand was estimated at 2,700 GWh (2012) at the consumer level. Taking into account losses during transmission and distribution of electricity, the deficit at the generation level amounts to about 3,100 GWh during winter compared to total winter supply requirement of 11,200 GWh, a gap of about 24 percent. The corresponding deficit in the system's firm capacity is about 1,250 MW.

About 70 percent of the population currently suffers from blackouts during the winter, imposing direct costs in terms of (1) foregone revenue from economic activity; (2) additional costs due to damage to equipment and interruption of business processes; and (3) costs from household equipment damage. In addition

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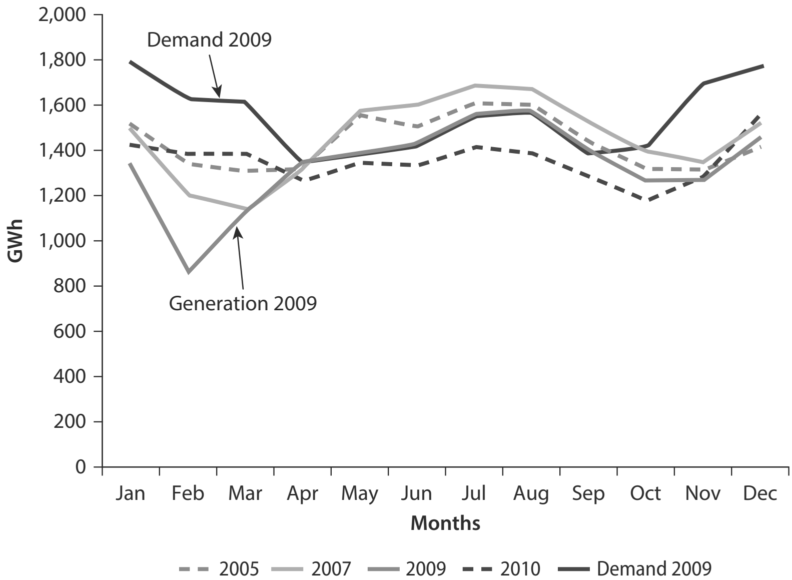
Figure 2.2 Monthly Electricity Generation, 2009



Source: World Bank data.

to the economic burdens of an electricity system in crisis, there are difficult consequences for Tajikistan's households as well. During the winters in Tajikistan, when residential electricity is available intermittently, households warm their homes by burning solid fuels (wood and coal predominantly). As a result, the incidence of carbon monoxide poisoning due to indoor air pollution is high. The World Health Organization lists Tajikistan among the 20 worst-affected countries for diseases resulting from indoor air pollution. Household burning of solid fuels is a major health risk factor in Tajikistan and particularly affects women and children. Staying warm becomes a preoccupation for families and overrides the risks of fire and poor indoor air quality.

Unreliable electricity supply also has a negative impact on the development of business opportunities. For example, the World Bank's Business Economic Environment Survey of 2008 reported that 80 percent of firms cited power supply reliability as a major obstacle to doing business in Tajikistan. It is mainly the demand of residential, government and other customers that is not served when generation capacities are insufficient to meet total demand. The agricultural sector is not affected by winter shortages as demand is largely restricted to the summer months when water-intensive crops such as cotton require irrigation. The cost of unmet demand is roughly estimated at US$200 million per year, or about 3 percent of GDP.

Demand Projections

Demand for electricity and the need for additional supply will continue to grow even as Tajikistan endeavors to meet current winter shortages. Demand

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Table 2.1 Unconstrained Growth in Demand

	2012	*2016*	*2020*
Peak demand before tariff and energy efficiency (MW)	3,500	4,110	4,710
Deficit before measures (MW)[a]	1,250	1,840	2,550
Winter energy demand before tariff and energy efficiency (GWh)	11,213	13,215	15,181
Winter shortage before measures (GWh)	2,700	4,510	6,800

Source: World Bank data.
Note: GWh = gigawatt hour; MW = megawatt.
a. Accounts for capacity additions gained during rehabilitation of existing assets.

projections are developed in three steps: unconstrained demand; economically efficient demand; and measures to curtail demand growth (table 2.1). The projections cover residential and nonresidential demand, but assume TALCO's demand remains constant.

Economically Efficient Demand and Willingness to Pay

Because this analysis of power supply options is carried out in economic terms, the forecast of electricity demand used reflects the demand for electricity that is consistent with economic efficiency principles. In principle, this demand is the estimated quantity of electricity that consumers would consume if they had to pay a price that fully covers the economic cost of supplying that amount of electricity. This approach does not necessarily predict that electricity prices will actually equal this economic cost of supply. But if these prices do differ from the economic cost, then the amount of electricity consumed would not equal the economically efficient level of consumption. If the prices were below the economic cost, consumption would exceed the economically efficient level, and this difference would impose an economic cost on society.

The methodology for deriving a forecast of the economically efficient level of electricity demand over the long term is therefore based on a model of the relationship between electricity demand growth and both real-income growth rate and real electricity price growth rate. This model is described in box 2.1.

To estimate economically efficient demand, the unconstrained demand projection is modified to incorporate the conserving effect of price, specifically, a price that reflects the economic cost of supplying power to meet the forecast consumers' demand for electricity. Conventionally, in the derivation of electricity demand forecasts, this price signal assumes that the electricity price is increased incrementally to fully cover costs of supply. This approach broadly satisfies the requirement for economic efficiency, although in practice it recognizes that consumers need time to adjust their electricity usage to price increases without undue disruption.

At 2.25 cents per kWh, Tajikistan's current electricity tariffs are among the lowest in the world. It is also noteworthy that electricity as a share of total household expenditures (less than 2 percent) is lower than in Kyrgyz Republic, Moldova, and Armenia, as well as a dozen other Commonwealth of Independent States (CIS) countries (Laderchi, Olivier, and Trimble 2012). As the need for

Box 2.1 Electricity Demand Growth Model

The methodology for deriving a forecast of the economically efficient level of demand for electricity over the long term is based on the following relationship between electricity demand growth and real-income growth and real electricity price growth, assuming a constant elasticity power demand function:

The rate of growth of demand is equal to the rate of growth of prices times the price elasticity plus the rate of growth of income times the income elasticity. This is expressed formally as follows:

$$d = p * b + g * a$$

where:
d = average rate of growth of demand between successive forecast periods
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 demand for electricity derived with this model is the forecast unconstrained end-use consumption without reduction of losses from the present level. This forecast end-use consumption is then transposed into the gross energy delivered to the power network from power generation plants needed to supply forecast unconstrained end-use consumption.

new supply increases, the gap between the tariff and the cost of new supply will increase; if not addressed, this could lead to overconsumption and an unsustainable subsidy of billions of dollars by 2020.

However, the conventional price adjustment methodology—to increase tariffs to cover costs of supply—will be difficult in Tajikistan. This is because Tajikistan has relatively low electricity prices and the estimated incremental cost of fully covering costs of new supply, based on the identified range of alternatives, will significantly exceed the current average tariff of 2.25 cents per kWh (2012).

If Tajik electricity prices were increased to cover the cost of new supply, however gradually, they would impose huge strains on the budgets of Tajik households and other electricity users, who would in turn react by decreasing their use of electricity at considerable economic and social costs. The resulting drop in future demand for electricity would be sufficiently large to substantially reduce the amount of new electricity supply capacity needed to meet future demand. The available data and information are insufficient to determine how the economic and financial benefits from a larger power sector investment program would compare with the loss of income by consumers under a major increase in electricity prices.

Tajikistan's Winter Energy Crisis: Electricity Supply and Demand Alternatives
http://dx.doi.org/10.1596/978-0-8213-9967-5

The World Bank recommends that the GoT seek a course that runs between moderating the increase in electricity tariffs to affordable levels for consumers and moderating the subsidies required by the power sector to ensure economically efficient levels of demand are met. A working solution would be to raise tariffs to the level of willingness to pay, as described below, which would increase tariffs to about 60 percent of the economic cost of meeting forecasted growth in electricity demand.[5]

Willingness to pay (WTP) is the maximum amount consumers are willing to pay for electricity. An indicative analysis of WTP was undertaken to estimate the value of unserved demand used for the evaluation of electricity supply expansion programs in Tajikistan in this study.

This approach yielded the following levelized values for WTP for the projected amount of unserved winter energy demand in the next few years under the power development program:

- For residential consumers: 4.6 cents per kWh consumed
- For all nonresidential consumers as a group: 10.4 cents per kWh consumed.

Because residential consumers account for about 44 percent of total demand, the estimated weighted average value of Tajik WTP for marginal power consumption under this approach is about 7 cents per kWh consumed; that is, current tariffs amount to about 30 percent of the value consumers place on the electricity they use, resulting in overconsumption. Applying the WTP approach to the demand model in box 2.1, the price signal assumed to consumers increases from the 2012 level of 2.3 cents per kWh to the WTP level of 7 cents per kWh by 2025, remaining steady thereafter. This price trajectory is also expected to more accurately reflect the financial needs of the sector to meet its considerable investment requirements. (See appendix C for more detailed description of the estimation of WTP.)

The influence on demand is significant. Between 2014 and 2025, if electricity prices increase from 2.25 cents per kWh to 7 cents per kWh, the average annual growth rate in demand is only between 1 and 1.8 percent. Afterwards, annual demand growth rates are up to 3 percent, resulting in an average annual rate of about 2.9 percent to 2040. This demand forecast reflects the full demand model in box 2.1, namely demand consistent with principles of economically efficient levels of consumption. The tariff increase would reduce electricity demand by about 1,300 GWh or 9 percent of annual demand by 2020.

Although an important method for moderating demand for investments in new electricity supply, a tariff increase to the level of WTP (from the current level of 2.3 cents per kWh to 7 cents per kWh) requires careful management. Even a graduated increase from 2014 to 2025 implies an increase each year of about 11 percent, with consequent pressure on household budgets. An appropriate tariff policy requires an accompanying program of DSM measures at the customer level to reduce demand for electricity and moderate the impact of increasing tariffs on total household energy bills.

Tajikistan's Winter Energy Crisis: Electricity Supply and Demand Alternatives
http://dx.doi.org/10.1596/978-0-8213-9967-5

In addition, social safety nets should be developed to protect lower-income and vulnerable communities. Much has been learnt over the last decade on how to ensure affordability of energy for lower-income and vulnerable communities. Emerging best practice points to the need to link closely transfers intended to compensate for higher energy costs with existing well-targeted social assistance programs. Ideally, this implies adding an energy component as a "top-up" of social assistance, although other poor groups which are above the eligibility threshold for social assistance of last resort could also be eligible for the energy benefit, as in the new energy benefit in Moldova (box 2.2). Adopting the same targeting mechanisms (either means tested or involving proxy means testing) across social assistance of last resort and energy benefits, and using the same administrative capacity to deliver both benefits, can keep down administrative costs and demands on local capacity, while making it easier for beneficiaries to apply.

Tajikistan is investing in a more modern and effective social assistance system, with stronger targeting mechanisms than in the past. A planned expansion of a pilot program introduced in 2011, from 2 to 10 districts in 2013, offers an opportunity for testing the introduction of a new energy benefit as part of social assistance reform. Linking a new benefit as a top-up to the existing one could also enhance the "attractiveness" of social assistance to potential beneficiaries, therefore increasing its effective coverage. The energy benefit should seek to guarantee adequate consumption levels while delinking effective energy consumption from the benefit; this approach will reinforce the incentives to save energy. Important design features to be studied include eligibility threshold for the benefit, possible conditionalities related to bill payment, the frequency with which beneficiaries should be certified as eligible and by whom, and the modalities of payment of the subsidy and its duration (only heating

Box 2.2 Strengthening Safety Nets and Energy Programs in Moldova

The Moldovan government has created a new means-tested social assistance program (Adjutor Social) which includes a new targeted heating allowance program for a few months of the year. The new energy program was first focused on recipients of social assistance of last resort (LRSA) only and then expanded to cover those within the 1.5 band of the minimum-income threshold guaranteed by the LRSA.

While introducing this new scheme (and freezing eligibility for another program which was not means tested), great care was put into introducing temporary measures (a 3-month flat payment to selected categories of beneficiaries) and also into clearly communicating them. While adopting a common targeting mechanism, it is important for individuals to perceive that the benefit involves two components—one of which specifically aimed at addressing rising energy tariffs.

Source: World Bank 2011a.

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season or yearlong). In addition, the desirability of low-cost complementary actions such as allowing households to smooth energy payments over the year to diminish pressures on their budgets during the winter should be explored.[6]

Fuel Switching and Energy Efficiency Measures (Including Energy Loss Reduction)

Demand growth and the need to invest in new supply can be further contained through fuel switching and a variety of energy efficiency measures. Fuel switching and energy efficiency measures could reduce the demand by 1,900 GWh or 13 percent by 2020, equivalent to about 29 percent of the winter energy deficit estimated for 2020 (in the absence of any additional measures).

Fuel switching

Fuel switching can reduce residential winter electricity demand by 357 GWh or 2 percent by 2020 if the share of urban households connected to coal-based district heating (DH) system increases from the current level of 15 percent to 65 percent by 2022.

In the past, heating demand of around 35 percent of urban households[7] was met with centralized heat supply systems run on natural gas and/or fuel oil (box 2.3). However, most of the households switched to electricity-based heating using electric heaters and some are using custom-made stoves run on coal or

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Box 2.3 Overview of Existing District Heating Systems in Tajikistan

District Heating (DH) systems in Tajikistan are available only in the capital city of Dushanbe and the region of Yavan. Dushanbe DH system comprises a Combined Heat and Power Plant (CHP) and a number of large and small boiler houses located in various parts of city. Several of those heat generation facilities are obsolete and require rehabilitation. Yavan CHP supplied heat to residents of Yavan urban area, however, the CHP is no longer operational. The main heat generation facilities, several of which can supply heat if fuel is available, include the following:

Table B2.3.1 Heating Systems in Tajikistan

Facility	*Type of fuel*	*Installed capacity (MW)*	*Available capacity (MW)*
Dushanbe CHP-1	gas/fuel oil	198	145
Yavan CHP	gas/fuel oil	120	0
Western boiler house	gas	760	348
Eastern boiler house	gas	80	40
6 coal-based boiler houses	coal	33	33
Other small boiler houses	gas and fuel oil	25	25
New midsize boiler house	gas and other	80	80
TOTAL		**1,296**	**671**

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Tajikistan's Winter Energy Crisis: Electricity Supply and Demand Alternatives
http://dx.doi.org/10.1596/978-0-8213-9967-5

Box 2.3 Overview of Existing District Heating Systems in Tajikistan *(continued)*

The heat transmission and distribution network includes 125 km of heat supply mains and 414 km of other piping. Lack of maintenance and obsolescence of the system resulted in high level of heat losses ranging between 40 percent and 50 percent. The system needs significant investments in rehabilitation of supply, transmission, and distribution levels. A long absence of centralized heating supply and limited maintenance of facilities resulted in the deterioration of infrastructure at the building level, requiring the rehabilitation of generation facilities and the replacement and/or proper insulation of transmission pipelines. Specifically, residents of multiapartment buildings and houses have removed in-house pipes and radiators.

firewood due to: (1) disruptions in gas supply from Uzbekistan due to disputes over payments and other contractual issues; (2) increasingly unaffordable imported gas (starting from 2012, the border price of Uzbek gas for Tajikistan increased to more than US$300 per TCM); and (3) deterioration of DH systems due to years of underspending on maintenance. Local boiler houses have been shut down for a variety of reasons. For example, the town of Tursun-Zade had a heat supply system owned by TALCO that was shut down five to seven years ago due to financial reasons. Although it would require rehabilitation, the heat could be recovered from waste heat generated during the production of aluminum.

Substituting the electricity-based heating of urban households with centralized coal-based heat supply would reduce the winter electricity demand significantly. Coal-based heating is estimated to cost about 5 cents per kWh[8] so fuel switching would be economically viable and financially attractive for households. However, when planning the fuel switch, the GoT should consider that residential customers will need a financial incentive to switch to coal-based district heating systems.[9] With the current residential electricity tariff of 2.25 cents per kWh, switching to coal-fired district heating systems will not be attractive for residential customers. Consequently, either an electricity tariff increase or an incentive program will be needed to realize these potential savings.

Fuel switching has proven to be a successful strategy in other countries (box 2.4). However, the potential in Tajikistan is more modest due to the following factors:

- Seventy 70 percent of the population lives in rural areas and accounts for 38 percent of residential electricity consumption. Opportunities for fuel switching in rural areas are limited and households primarily rely on electricity-based heating or, if service is not available, already use other fuels (e.g., dung and firewood).
- Significant new investments might be required to increase the coal production from the current level of 50–60 thousand tons/year to a level sufficient to fuel the planned coal-fired thermal plants and other boilers to meet the heat demand of urban households.

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Box 2.4 Fuel Switching in Armenia

In the seven years from 2002 to 2009, Armenia reduced the share of firewood and electricity-based heating in multiapartment residential buildings from 90 percent to 26 percent and increased the share of gas-based heating from 13 percent to 71 percent. The switch to more efficient and affordable heating was driven by a number of key activities structured around the Urban Heating Strategy of the government and implemented with donor support. In 2001, urban households in Armenia almost entirely relied on firewood and electricity for heating. As a first step to facilitate access to efficient, clean, safe, and affordable heating services, the government adopted the Urban Heating Strategy (UHS) in 2002. The UHS provided the strategic framework for the short-, medium- and long-term development of an urban heating sector that was affordable and environmentally sustainable. The key factors that contributed to the rapid switch of urban households to the gas-based heating option (primarily individual gas boilers) included the following:

- Improvement of legal and regulatory framework to support the introduction of gas-based heating
- Mobilization of the private sector for provision of heat supply equipment and services
- Provision of financing to consumers for investments in heat supply systems
- Provision of capital grants to the poor for connection to the gas service
- Rapid gasification rates in the country.

Source: World Bank 2011b.

Investment cost: The estimated investment cost of switching 50 percent of urban households from electricity to coal-based heating is estimated at US$85 million during 2014–20. This includes the investment costs for coal-based district level boiler houses as well as heat distribution infrastructure.

Energy efficiency measures

Two categories of energy efficiency measures were considered in the analysis:

- Continued technical loss reduction program, which will ensure more electricity is delivered to end-users
- Demand-side energy efficiency measures, which will help reduce winter demand while ensuring use of or access to the same services.

Reduction of electricity losses: Reduction of technical losses from the current level of 18 percent to 12 percent would reduce winter demand by 771 GWh or 5 percent by 2020. Transmission and distribution (T&D) losses in Tajikistan are estimated at 18 percent of supply.[10] This is 3–5 percent above T&D losses in other ECA countries with T&D systems of similar age and characteristics. The GoT has made some progress with loss reduction in the Dushanbe area with support of the World Bank Energy Loss Reduction Project, and is implementing a follow-up

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project in the Dushanbe area[11] as well as in the Sugd region. Opportunities exist to scale up loss reduction program to include other regions.

Improvement of demand-side energy efficiency: Tajikistan is considered a medium-energy-intensive country (0.20–0.30 kgoe per gross domestic project) with an estimated energy intensity of 0.21 kgoe per gross domestic project, comparable to Serbia, Estonia, and the Republic of Belarus. It is more energy efficient than other Central Asian countries with energy intensities in the range of 0.25–0.73 kgoe per gross domestic project.[12]

There are a number of lessons that can be drawn from the successful experience of energy efficiency improvements in other ECA countries. For example, Belarus, Lithuania, and Romania reduced energy intensity by around 50 percent between 1990 and 2007 through a combination of structural changes and energy efficiency investments. Key policy measures the GoT should consider to improve energy efficiency include, but are not limited to setting prices to reflect cost of energy supply, embedding energy efficiency in the legal framework, developing and effectively implementing energy efficiency action plans, and ensuring energy efficiency standards for appliances and buildings (Stuggins, Sharabaroff, and Semikolenova 2012; box 2.5).

Box 2.5 Lessons from Successful Energy Efficiency Measures in Belarus, Lithuania, and Poland

A number of lessons can be drawn from the successful energy efficiency improvements in other ECA and EU countries, including Belarus, Lithuania, and Poland. These countries managed to reduce energy intensity by around 50 percent over 1990–2007. Specifically, the GoT should consider a number of actions that can be replicated in Tajikistan to reduce energy efficiency:

- Increasing tariffs to full short-term cost-recovery levels
- Establishing an entity responsible for guiding EEPs
- Establishing energy efficiency targets and a National Energy Efficiency Action Plan
- Improving the legal and regulatory framework to support energy efficiency investments
- Establishing appliance standards
- Encouraging building certificate programs
- Providing affordable financing for energy efficiency investments
- Encouraging the use of ESCOs
- Raising public awareness about the benefits of energy efficiency.

Belarus reduced its energy intensity from 0.68 kgoe/GDP in 1990 to 0.24 kgoe/GDP in 2009, which is below the ECA average of 0.27 kgoe/GDP. This was driven by strong political commitment (establishment of a designated energy efficiency agency as well as adoption and implementation of National Programs on Energy Savings) and significant investments in energy efficiency, estimated US$4.2 billion in 1996–2008.

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Box 2.5 Lessons from Successful Energy Efficiency Measures in Belarus, Lithuania, and Poland *(continued)*

Lithuania reduced its energy intensity from 0.37 kgoe/GDP in 1990 to 0.17 kgoe/GDP in 2009. Poland reduced its energy intensity from 0.33 kgoe/GDP in 1990 to 0.16 kgoe/GDP in 2009. The successful EEPs in these countries hinged upon a number of common elements, including (1) rapid increase of electricity tariffs to match supply costs; (2) establishment of a designated Energy Efficiency Agency; (3) quick improvements to legal and regulatory framework to align with EU; (4) establishment of building regulations; and (5) grant financing to support energy efficiency investments in housing stock.

Source: Stuggins, Sharabaroff, and Semikolenova 2012.

The GoT informed the World Bank that it has already completed implementation of the program to replace old incandescent lamps with compact fluorescent lamps (CFLs) for all households across the country. This is a significant achievement. Although there is no data available yet to estimate the electricity savings, banning incandescent light bulbs suggests that further potential for additional energy savings from lighting is limited. The GoT has also introduced various energy savings technologies in construction, with accompanying regulatory legal acts. However, several other alternative measures are available. This study explored the following:

1. Energy efficiency at TALCO
2. Residential building insulation
3. Energy efficiency standards
4. Labeling for household appliances and solar heating.

The estimates of electricity saving potential of TALCO are based on the results of ongoing analysis of energy use financed by the World Bank, following the request of the GoT. The savings from fuel switching and energy efficiency measures are derived from high-level estimates and are considered as base-case energy efficiency scenarios throughout this study.

Improvement in EE at TALCO: Although electricity consumption at TALCO has fallen over the past three years, the current energy analysis suggests that further energy efficiency measures could reduce winter demand by 531 GWh or 3 percent by 2018.

Aluminum production is highly electricity intensive, with the electrolysis process requiring 10–17 kWh per kg of aluminum, depending on the age and type of technology used. TALCO consumes about 17 kWh to produce 1 kilogram of aluminum, at the upper end of the industry range. A number of energy efficiency measures were identified for TALCO: (1) change of technological processes (electrolyses and anode production); (2) improvements in efficiency of

Tajikistan's Winter Energy Crisis: Electricity Supply and Demand Alternatives
http://dx.doi.org/10.1596/978-0-8213-9967-5

autonomous boiler house; (3) better insulation; and (4) replacement of lighting (see detailed description of measures in appendix D). Most of those measures could be realized within four years and could substantially reduce the winter deficit. It should be noted that the short-term measures will start generating electricity savings one year after implementation.

Electricity consumption of TALCO can be further reduced if the periodic replacement and maintenance of electrolytic pots is carried out during winter months. This can create additional savings of winter electricity of about 150 GWh, which can be supplied to residential and other end users. However, the GoT needs to conduct a detailed and comprehensive assessment to determine the feasibility of such measures to be implemented by TALCO during winter season (e.g., long-term contracts with suppliers and buyers).

The GoT has already agreed to start implementation of energy efficiency measures at TALCO. Specifically, the GoT issued a resolution adopting a time-bound action plan to implement its recommendations to reduce energy used per unit of production.

Box 2.6 Background Information on TALCO

The state-owned aluminum company (TALCO) is the largest consumer of electricity in Tajikistan accounting for 36–45 percent of total electricity consumption in various years. The smelter was constructed in the early 1970s in conjunction with the Nurek hydropower station that supplies electricity to the company. TALCO is the largest aluminum plant in Central Asia and the central element in Tajikistan's industrial base, accounting for around 5–7 percent the GDP and around 40 percent of exports. Approximately 10,700 workers are employed by the company.

Most aluminum industry inputs are imported to Tajikistan with prices dictated by international markets. The main local inputs are electricity and labor. TALCO's profitability is also dependent on the international price of aluminum and the major inputs (primarily alumina). However, the profitability of TALCO is highly dependent on electricity tariffs because electricity accounts for more than 50 percent of total production costs. In 2011, TALCO's energy costs were US$108 million consisting of US$92 million for electricity and US$16 million for gas.

The TALCO electricity tariff has historically been quite low; however, it was increased in 2007–11 reaching an equivalent of 1.8 cents/kWh in 2012. The prices charged to TALCO reflect the cost of supply from the Nurek hydropower plant which was built to serve the needs of the aluminum smelter. Since April 2012, seasonal tariffs have been introduced for TALCO and the company will be paying 1.3 cents/kWh in summer and 2.2 cents/kWh in winter months. This corresponds to an estimated weighted average tariff of 1.8 cents/kWh. In 2011, TALCO consumed about 46 million cubic meters of natural gas and 7.6 GWh equivalent of heavy oil. The gas bill increased from US$13 million in 2009 to US$16 million in 2011 due to the increase in gas tariff, despite an 8 percent decrease in consumption.[13]

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http://dx.doi.org/10.1596/978-0-8213-9967-5

Box 2.6 Background Information on TALCO *(continued)*

The electricity price charged to TALCO is typical of prices charged to aluminum smelters in the Russian Federation, but is roughly 1 cent/kWh less than global averages. However, TALCO's production costs are relatively higher due to problems with power supply disruptions that took 60 of its 900 pots out of service. Improving the reliability of supply and investments in energy efficiency to avoid a similar supply disruption in the future would reduce TALCO's production costs and enable electricity prices to better reflect industry norms.

Investment cost: The total investment cost of TALCO energy efficiency measures is estimated at US$87 million during 2013–17, including US$7 million for short-term measures and US$80 million for medium-term measures. Most of the measures are estimated to have a payback period of around 2 ½ years on average, are profitable to TALCO, and do not require government financing. The unit cost of electricity saving is estimated at 0.1 cents per kWh for short-term measures and 2.2 cents per kWh for mid-term measures—rendering it among the least-cost options for reducing demand.

Other EE measures on the demand side, including insulation of residential buildings/apartments, introduction of energy efficiency standards, and labeling as well as solar heating, can reduce winter demand by 103 GWh or 1 percent of winter energy demand by 2020 and would require around US$72 million of investments.

1. **Insulation of residential buildings**. Space heating accounts for 70 percent of annual electricity consumption of an average household, which is an opportunity for improved building insulation. Based on regional experience, energy efficiency savings of 30–40 percent are attainable from improved building insulation. If 30 percent of urban residential households implements insulation of their apartments by 2022, winter demand could be reduced by 25 GWh[14] or 0.2 percent by 2020.
   Investment cost: The data from energy efficiency projects in other ECA countries suggests that the costs of comprehensive building insulation measures, depending on the size of the residential space, are about US$90 per square meters. However, given income levels in Tajikistan, only basic measures with short pay-back periods are considered affordable and would cost about US$20 per square meters. Such investments in roof insulation and calking of air leaks typically reduce energy losses by 20 percent. International experience also suggests that government support would be required to promote building insulation in excess of the "natural" rate of apartment or house reconstruction undertaken by residents. Thus, the GoT should consider conducting a comprehensive energy efficiency study for the residential sector using low cost or grant financing from sources of funds that support this global public good.
2. **Introduction of energy efficiency standards, labeling for household appliances**. With continued economic growth, demand for household appliances

Tajikistan's Winter Energy Crisis: Electricity Supply and Demand Alternatives
http://dx.doi.org/10.1596/978-0-8213-9967-5

will increase, presenting a good opportunity to ensure that households purchase energy efficient appliances.[15] After the successful introduction of compact fluorescent lighting in Tajikistan, additional savings could be realized with use of energy efficient refrigerators. The saving potential from introduction of energy efficient refrigerators only is estimated at 65 GWh or 0.4 percent of winter energy demand by 2020.

Investment cost: The only costs the GoT will need to finance relate to preparation and implementation of the standards and labeling program and are estimated at US$5 million. The costs of new appliances are borne by residents who would be purchasing new or replacing existing appliances anyway. The purchase decision is taken based on product features and overall costs during a product's life time, so electricity consumption will play a role. The unit cost of electricity saving from introduction of standards and labeling is estimated at 2 cents per kWh.

3. **Increased use of solar water heaters**. The impact of solar heating systems on winter demand, as opposed to electric water heating, is expected to be negligible. Due to the limited solar irradiation during heating season, even if 30 percent of households install solar water heaters, it is estimated to reduce winter demand by 13 GWh or 0.1 percent by 2020.

   Investment cost: The total investment cost of solar water heaters is estimated to be at least US$47 million. The unit cost of energy from solar water heaters is estimated at 14 cents per kWh. The capital expenditure can be reduced if solar heaters are combined with investments in a new heating system. As long as electricity tariffs remain at current levels, investments in solar water heaters will remain comparatively unattractive. Hence, government support programs would probably be required to stimulate investments.

Demand Projections with Tariff Management, Fuel Switching, and Energy Efficiency Measures

The impact of tariff increase, fuel switching, and a full suite of energy efficiency measures is summarized in table 2.2. As shown, the possible reduction in winter demand is estimated at 3,250 GWh or 20 percent by 2020. The most significant impact is from a tariff increase from which a 9 percent reduction in winter demand could be achieved. Electricity loss reduction measures and fuel switching could reduce demand by 7 percent and TALCO measures by about 4 percent plus an additional 2 percent by shifting maintenance to winter months. The potential impact of these measures on the winter electricity shortages is significant: almost 50 percent of the deficit forecasted for 2,020 of 6,800 GWh could be eliminated even without building new generation capacity.

Figure 2.3 illustrates the demand projection with and without these measures to 2020 with the resulting demand projections detailed in table 2.3. The full impact of the above energy efficiency measures will materialize by 2022 because implementation of most measures would require 8–10 years to reach the estimated annual electricity saving targets. The effect of energy efficiency measures

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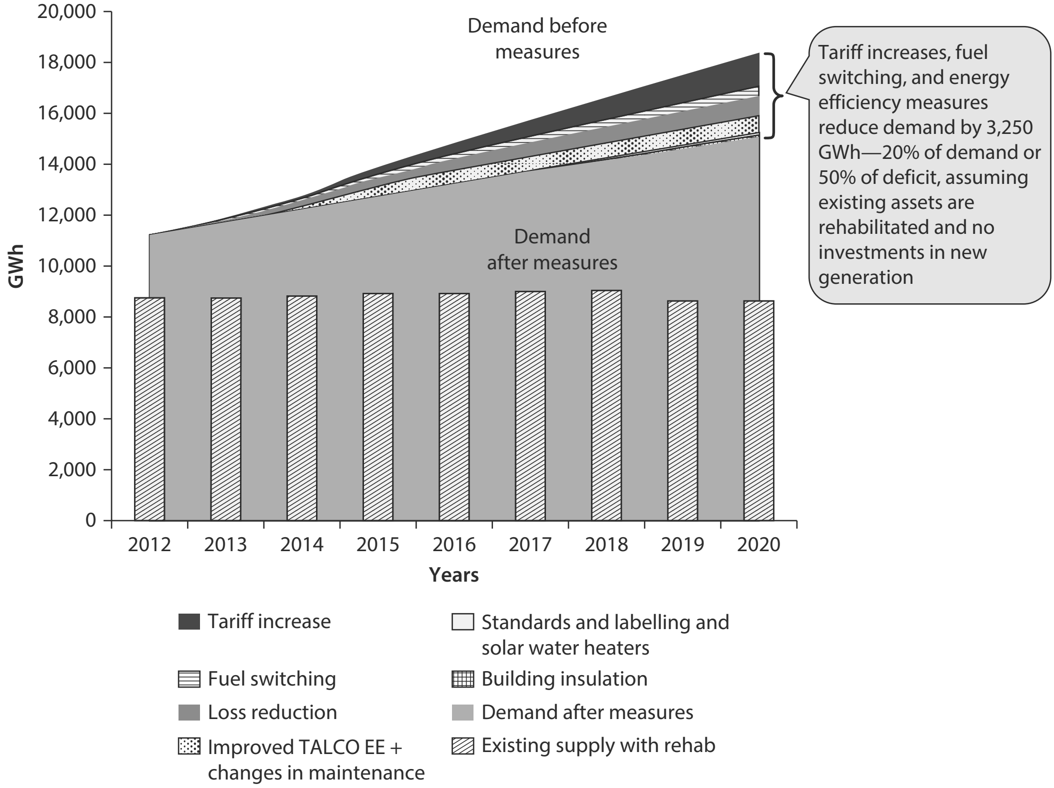
Table 2.2 Energy Savings and Costs of Energy Efficiency Measures

Measure	*Assumption*	*Winter Demand Reduction to 2020 (GWh)*	*Total Investment Cost to 2020 (US$ millions)*	*Unit Electricity Saving Cost (cents/kWh)*
Tariff increase	Increase to US$0.07/kWh by 2025	1,339	n.a.	n.a.
T&D loss reduction	Reduction from 18% to 12% in 2020	771	36	1
TALCO short-term measures	Improvements to the electrolyses process, anode production, and plant service by 2014	359	7	0.1
TALCO midterm measures	Further improvements to the electrolyses process, anode production and plant service by 2017	172	80	2
TALCO winter maintenance	Shift maintenance from summer to winter months	150	n.a.	n.a.
Switching from electricity to coal-based heating	Increase share of urban households with central district heating (coal-fired) from 15% to 65%	357	85	5
Building insulation	30% of urban residential households insulate apartments or houses	25	20	5
Standards and labeling	Introduction of energy efficiency standards and labeling for household appliances	65	5	2
Solar water heaters	Increased penetration of solar water heaters	13	47	14
Total		**3,250**	**280**	

Source: World Bank data.
Notes: GWh = gigawatt hour; kWh = kilowatt hour; n.a. = not applicable.

Figure 2.3 Impact of Tariff Increase, Fuel Switching, and Energy Efficiency on Demand, 2012–20



Source: World Bank data.

Table 2.3 Winter Demand with and without Tariff Increase, Fuel Switching, and Energy Efficiency
GWh

	2012	*2013*	*2014*	*2016*	*2018*	*2020*
Winter demand before tariff increase, fuel switching and energy efficiency	11,213	11,705	12,239	13,215	14,199	15,181
Winter demand after tariff increase, fuel switching and energy efficiency	11,200	11,535	11,706	11,580	11,738	11,930
Reduction in winter demand (%)	0.1	1	4	12	17	20

Source: World Bank data.

continues past 2022 as targets are maintained even as demand grows, although the impact diminishes thereafter.

Investment cost: Taken together, implementation of the above energy efficiency measures will require around US$280 million of investments in 2013–20. Most of the proposed energy efficiency measures are estimated to be economically attractive because the cost per kWh of electricity saved is below the

http://dx.doi.org/10.1596/978-0-8213-9967-5

estimated long-run electricity supply cost of over 10 cents per kWh. However, some of the measures, like increased penetration of solar water heaters, appear to have per kWh electricity costs above the estimated long-run supply costs of electricity.

It should be noted that the proposed and calculated savings from energy efficiency are of a preliminary nature. Although recent studies have been undertaken in the area of energy efficiency (e.g., the Energy Efficiency Master Plan for Tajikistan by UNDP in 2011), the database is still incomplete and insufficient for an in-depth quantitative analysis. The GoT should consider conducting a detailed assessment of the energy efficiency and fuel switching (including district heating) potential to make informed decisions about the economic and financial viability of energy efficiency measures.

Export Opportunities

The GoT considers the export of electricity as a major driver for economic growth and foreign exchange earnings. In summer, the amount of electricity generated by Tajik hydropower plants exceeds domestic demand. If this summer surplus is exported, it could generate income that reduces the size of future electricity price increases and is an important element for improving the financial condition of the power sector.

Currently Tajikistan has a power purchase agreement with the Islamic Republic of Afghanistan for the supply of firm energy during summer from Sangtuda HPP to Kunduz substation via a double-circuit 200 kilovolts line with a capacity of 300 MW. This firm summer energy export is considered in the demand projections because it represents demand that must be met. The export demand does not add to the peak load.

The level of surplus energy that the power system of Tajikistan could generate after meeting the domestic and firm export demand depends on the number and size of hydropower plants considered in the portfolios. How much of the surplus energy could be exported depends on the transmission lines linking Tajikistan with potential export markets in South Asia, such as Afghanistan, Pakistan, and India, and in Central Asia.

There are currently various projects under consideration, including the CASA-1000 project for the Central-Asia South Asia Regional Electricity Market, which involves plans for construction of a 500 kilovolts link between the Kyrgyz Republic, Tajikistan, Afghanistan and Pakistan. The first phase of CASA-1000 is to provide 1,000 MW to Pakistan and 300 MW to Afghanistan during summer months only, which is the peak demand period for Pakistan.

Another opportunity to be pursued is export to the countries of the CAPS, in particular Kazakhstan and Uzbekistan. This would involve revitalizing the energy trade that was gradually discontinued after the dissolution of the Soviet Union when the countries decided to reduce their mutual trade and become energy independent. Promotion of regional energy trade is in line with the objectives of the Central Asia Regional Economic Cooperation (CAREC).

Tajikistan's Winter Energy Crisis: Electricity Supply and Demand Alternatives
http://dx.doi.org/10.1596/978-0-8213-9967-5

Table 2.4 Assumed Export Opportunities for Tajikistan

	Capacity (MW)	Energy (GWh)	Investment Cost (US$ millions)	Commissioning Year	Export Tariff (cents/kWh)		
					Energy	Wheeling	Total
CASA 1000	1,300	2,400	250	2017	3.5	0.9	4.4
CASA Phase 2	1,300	4,000	750	2023	3.5	2.7	6.2
via UZB to CA	250	850	—	2021	3.5	0.5 (est.)	3.5
Maximum	**2,850**	**7,250**	**1,000**				

Source: World Bank data.
Note: Gwh = gigawatt hour; kWh = kilowatt hour; MW = megawatt; — = not available.

For the purpose of this study, the following export routes are considered (see table 2.4):

- CASA-1000 (1,300 MW) with a maximum annual energy export of 4,000 GWh (shared by the Kyrgyz Republic [40 percent] and Tajikistan [60 percent = 2,400 GWh] from 2017 onward
- CASA Phase 2 (1,300 MW) with a maximum annual energy export from Tajikistan of 4,000 GWh, from 2023 onward
- Export via Uzbekistan (UZB) to Central Asian (CA) Republics with a maximum annual energy export of 850 GWh from 2021 onward.

For the CASA-1000 project, US$250 million has been considered as Tajikistan's share in capital investment. For the CASA Phase 2, it is assumed that Tajikistan bears the total investment costs in Tajikistan, Afghanistan and Pakistan of US$750 million. These costs are to be recovered through the tariff. Export via Uzbekistan will use existing lines at no extra cost and assumes that barriers to trade are sufficiently addressed to enable synchronous operations of the CAPS by 2021. Assuming an energy tariff of 3.5 cents per kWh, based on the tariff agreed with Afghanistan and competitive pricing for summer surpluses, the total export tariffs (including recovery of estimated transmission costs) will be 4.4 cents per kWh for CASA-1000 and 6.2 cents per kWh for CASA Phase 2.

Under these assumptions, all exports are supplied through excess summer electricity generation. Over the 2012–20 period, transmission constraints do not justify additional investments in new power plants dedicated to the export market. Removing constraints to transmission could increase export potential in the summer.

Notes

1. Northern Kazakhstan was interconnected with the Russian grid.
2. Withdrawals by Tajikistan were reported to be greater than 100 GWh.
3. Such grid discipline problems are similar to the situation in India where an overdraw by a few states led to catastrophic failure of the grid in May 2012.

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4. The winter season is considered to be October to March.
5. Other sources of financing to meet overall costs are discussed in chapter 4.
6. Given the pilot nature of the consolidated new social assistance program, however, the readiness of the social assistance system should be assessed. Depending on the timing of tariff increases, temporary measures may need to be introduced while the social assistance system gears up toward full deployment at the national level. Temporary flat payments distributed to vulnerable categories (without means testing) can represent an effective way of providing protection in times of duress, without creating a new entitlement for recipients that would require more careful design and consideration.
7. District heating was available only in the capital city of Dushanbe and the administrative region of Yavan.
8. Estimated assuming long-run supply cost of hard coal at US$100 per ton.
9. The analysis does not account for other benefits of DH systems, such as improved comfort levels.
10. Excluding TALCO as it is connected only to high-voltage supply network.
11. World Bank supported Additional Financing for Energy Loss Reduction Project.
12. World Development Indicators Database, World Bank, Access on August 10, 2012.
13. World Bank estimates.
14. This is a conservative estimate assuming that basic energy efficiency improvements will start with multiapartment residential buildings in urban areas. Moreover, the actual energy savings are likely to be higher since the average household consumption in urban areas is likely to be higher.
15. This report estimates only the savings from replacement of old refrigerators with energy efficient models due to lack of detailed information on penetration rate of other household appliances.

Tajikistan's Winter Energy Crisis: Electricity Supply and Demand Alternatives
http://dx.doi.org/10.1596/978-0-8213-9967-5

CHAPTER 3

Alternatives for New Electricity Supply

Characteristics of the Existing Power Supply System

Tajikistan's power supply system is dominated by hydropower plants, most of which were built during the Soviet era. Hydropower plants account for 96 percent of the total installed capacity of 4,750 MW. However, the generation capacity is insufficient to meet an estimated peak load of 3,500 MW because of low river flows during the period of peak demand in the winter months. During winter, the system's firm capacity is reduced to 2,250 MW, 1,250 MW less than needed. This problem stems from two issues: (1) the limited amount of thermal plant capacity that can be operated full time at full capacity (base-loaded capacity) because of the characteristics of demand; and (2) only one hydropower plant—Nurek—has a reservoir, all others are run-of-river plants that experience low flows in the winter. The shortfall in base-load capacity forces hydropower plants to inefficiently operate base loaded as well, which was not their intended use.

The Government of Tajikistan (GoT) has already taken measures to strengthen energy security. For example, Sangtuda-1 Hydropower Plant (HPP) added 670 MW of capacity, and Sangtuda –2 (220 MW) is expected to begin full operation soon. These efforts have been critical in attenuating the winter energy shortages, but additional measures to bring demand and supply into balance in the near future are needed.

The Nurek hydropower plant is the cornerstone of Tajikistan's power system. At 3,000 MW, it represents more than 60 percent of the total installed capacity. The dam is 300 meters tall, making it the tallest dam in the world. The reservoir is 70 kilometers in length and covers 98 square meters. The original, primary purpose of the reservoir was to accommodate irrigation needs with energy use as a by-product.

Even with Nurek, Tajikistan's hydropower storage capacity is insufficient to meet the country's winter energy needs. There is adequate reservoir capacity to meet weekly variations in river flows, but not seasonal variations. As a result, Tajikistan is in the unfortunate situation of having excess capacity during the

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summer with limited market opportunities for sales. Water is spilled during the summer as the reservoir capacity in the system is inadequate to allow storage for the winter months when it is needed. Increasing reservoir storage capacity along the same river cascade would help mitigate this problem.

Energy efficiency measures described in chapter 2 are critical components in balancing electricity demand and supply. However, they are not sufficient. In order to eliminate winter shortages, and meet growing demand, new energy supplies are required. This chapter explores additions to power supply from a range of alternatives: hydropower plants, thermal sources (that is, coal, natural gas, and diesel), renewable energy resources, and imports ("Rehabilitation of Hydropower Plants," "Hydropower Development," "Thermal Power Plants," and "Imports"). It also covers the critical issues of protecting the capacity of existing assets through rehabilitation ("Characteristics of the Existing Power Supply System").

The initial list of supply options was taken from the stocktaking initiated by the World Bank as preparatory work for this study. The preparatory work involved the collection of existing studies, project proposals, system expansion plans and system assessments from the GoT, Barki Tajik (BT), development partners, and nongovernmental organizations (NGOs). In addition, other options were assessed that have not so far been considered by the GoT/BT but which could be potential sources of power in future: renewable energy sources, gas-fired power plants, emergency diesel power plants, and alternative import options.

In a prescreening process, alternatives were excluded for which realization within the next 10–20 years is highly unrealistic for technical reasons. This exercise took into consideration comments from the GoT and BT as well as the outcomes of a number of meetings with representatives of the Ministry of Economic Development. A revised list of supply alternatives was prepared by removing options that were as follows:

- Either no longer being pursued by the GoT/BT for certain technical, environmental, or social reasons or
- Not developed since they were originally assessed in a high-level master plan prepared decades ago, and thus do not provide useable project information.

New supply is assessed from the perspective of winter electricity demand when peak demand is high and river flows are low (January is the month of maximum demand in Tajikistan). Hence, additions are measured and prioritized based on firm rather than installed capacity. In addition, each supply alternative was assessed based on a set of economic, social, environmental, and technical criteria developed in consultation with the GoT. A complete list of alternatives and their characteristics is presented in appendix F.

Rehabilitation of Hydropower Plants

Protecting the 4,950 MW of existing installed capacity[1] in the Tajik system is key to meeting demand. Most of Tajikistan's hydropower plants have been in

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operation for an average of 45–50 years without major investments in upgrade or rehabilitation. This compares with industry norms of economic lives of 25 years for hydropower equipment and 50 years for civil works. Most of the old HPPs require rehabilitation or replacement of turbines, generators, transformers, and other key pieces of electro-mechanical equipment. Those HPPs also require rehabilitation of civil works, including the removal of debris and other obstructions from tailrace canals. For some projects, namely Nurek, sedimentation poses an equally difficult challenge to maintaining capacity.

The GoT realizes that the rehabilitation of hydropower plants in operation is a priority measure to recover the energy system and to ensure energy security in the country. This year modernization of Varzob-1 HPP is being finalized, and construction of Switchgear-220 kilovolts of Nurek HPP and modernizing the 4th hydro unit of the main HPP are under way. Construction projects of Switchgear-500 kilovolts at the Nurek HPP have been started and are to be finalized between 2013 and 2015. Between 2012 and 2016, the GoT is prioritizing three large HPPs for rehabilitation: Nurek, Kairakkum, and Golovnaya (Sraband). The sources of financing for rehabilitation of Kairakkum and Golovnaya HPPs have been (at least partially) identified (that is European Bank for Reconstruction and Development (EBRD) for Kairakkum (started 2012) and Asian Development Bank (ADB) for Golovnaya (in 2013)). The World Bank is initiating a feasibility study for rehabilitation of Nurek within the framework of the Additional Financing for the Energy Loss Reduction Project, but financing for needed works has not yet been identified.

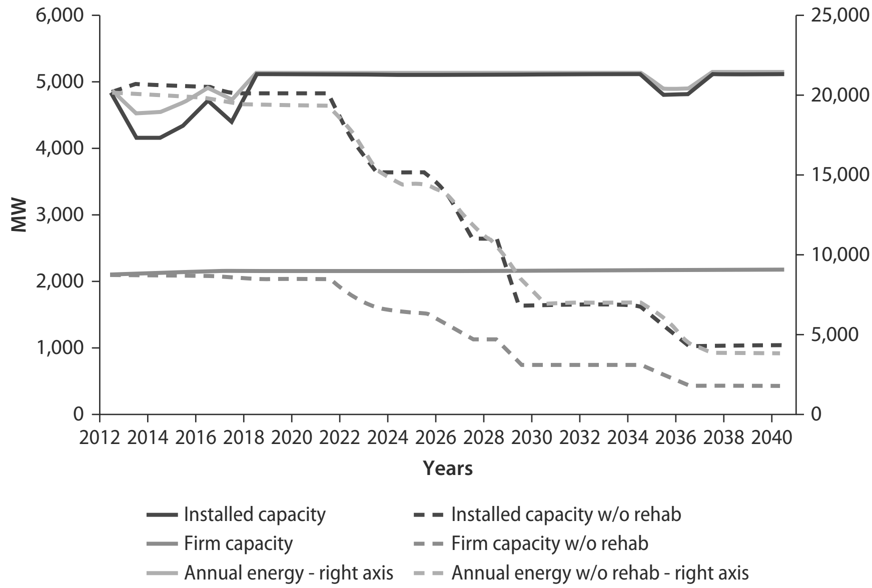
Projected rehabilitation measures are based on a schedule provided by GoT. Where no data were available, it is assumed that plants are rehabilitated at the end of the typical technical lifetime. Under these assumptions, about 60 percent of the current stock of hydropower assets should be rehabilitated by 2020 and close to 80 percent by 2030. In the absence of rehabilitation, firm capacity of hydropower plants could fall from the current level of 2,100 MW to 760 MW by 2030 (figure 3.1).

Rehabilitation also offers an opportunity to increase the electricity generation per unit of water. Such upgrades are conservatively estimated to increase firm capacity by 2.5–5 percent or an additional 65 MW, which will provide additional 260 GWh of electricity. A detailed list of HPPs with rehabilitation works and projected increase in firm capacity is presented in appendix E.

Compared with new power plant construction, rehabilitation is typically the more economical option. However, the current stock is so aged that the total cost of rehabilitation of HPPs is estimated at US$1.1 billion during 2013–20. Rehabilitation projects worth US$400 million are under way and are expected to be completed by 2014. The magnitude of anticipated work coupled with the complexity inherent to rehabilitation projects and the imperative of keeping capacity available during winter months warrants a detailed plan with priorization and contingencies.

Tajikistan's Winter Energy Crisis: Electricity Supply and Demand Alternatives
http://dx.doi.org/10.1596/978-0-8213-9967-5

Figure 3.1 Firm Hydropower Capacity and Electricity Generation of HPPs "with" and "without" Investments in Rehabilitation



Source: World Bank data.
Note: This figure includes the effect of sedimentation at Nurek, but does not include the impact of increased capacity from upgrading during rehabilitation at any plant.

Hydropower Development

There is enormous hydropower potential in Tajikistan with only 5 percent of the estimated technical potential has been developed. The GoT has identified 22 run-of-river HPPs for development with an estimated total installed capacity of 13,000 MW. These are located in three river basins (Vakhsh/Zaravshon, Obi-Hingou and Pyanj) and range in size from 90 MW to 2,100 MW.[2]

Despite the magnitude of the hydropower potential, HPPs have several limitations. Most significantly, lower river flows and cold weather reduce winter electricity generation, particularly from nonstorage HPPs. In the current system, winter energy generation is about 70 percent of summer generation; among the 22 run-of-river identified projects, expected winter generation is about 40 percent of summer generation.

Firm capacity is estimated based on flows and months of highest demand (box 3.1), so the contribution of HPPs to meeting winter peak demand is limited. For example, despite an installed capacity of about 5,000 MW, the current system can only provide a firm capacity of approximately 2,200 MW during winter. The impact of low flows is similarly dramatic for small HPPs. A package of 60–70 projects with total installed capacity of 35 MW supplies only 7 MW in winter. In some cases, installed capacity is up to 8–10 times the calculated firm capacity (table 3.1). On average for the projects identified, firm capacity is equal to only about 25 percent of installed capacity.

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Using only run-of-river, many more hydropower plants need to be built to meet firm capacity needs, increasing financing needs. This also leads to high costs of firm capacity, far exceeding the cost of installed capacity, and, in some cases, the cost of thermal plants. As shown in table 3.1, the unit cost of firm capacity ranges from 10 cents per kWh to more than 36 cents per kWh, with four exceptions. High installed capacity will support higher level of generation in the summer months of high flows. However, without available export markets, surplus of electricity during summer cannot be sold, which affects the financeability of such plants.

Few HPPs are investment ready because they lack feasibility studies that meet international standards. Consequently, the soonest any HPPs can expect to be fully commissioned is 2020. Furthermore, a large proportion of identified projects are located on the Pyanj River, a major tributary of the Amu Darya, and shared with Afghanistan, and may encounter further complications (such as share of power generated) due to their transboundary nature.

The GoT is in the process of completing comprehensive assessment studies on the proposed Rogun Hydropower Project, a 3,600 MW project on the Vakhsh River. The studies will examine energy production, dam safety, hydrology, downstream flows, social and environmental impacts, economic viability, and

Box 3.1 Estimating Firm Capacity from Hydropower Plants

Various definitions of firm capacity for hydropower plants are discussed in the literature. Generally, it is stated that the definition of firm capacity has to be seen in the context of demand and the time period during which the system proceeds from full storage to minimum storage. In the *Civil Engineering Guidelines for Planning and Designing Hydroelectric Development* of the American Society of Civil Engineers, the dependable (firm) capacity based on the critical month method is defined as follows: "The traditional definition of dependable capacity is based on the hydro project's load-carrying capability under conditions that are most adverse from the standpoint of both load and flow. Thus, a storage project's dependable capacity is based on its capability in a high demand month near the end of the reservoir drawdown cycle, when its capacity would be reduced due to reduced head."

Applying this to the context of the Tajik power system, if the second half of the winter period is defined as the period near the end of the reservoir drawdown cycle, from a demand perspective January would be the relevant month, since this is when the peak demand occurs. Available capacity in January of the existing storage plant (Nurek) is taken as the basis for determination of firm capacity. To be consistent with the definition of the firm capacity of storage plants, the capacity of run-of-river HPPs is estimated on the same basis. Hence, firm capacity is taken to be the available capacity in January—the month of peak demand, even though, from a purely hydrological point of view, available capacity is lowest in March, when flows are lowest. The firm capacity estimates used in this report are static, based on the current generation mix in the Tajikistan grid. Changing the generation mix in the future would change the firm capacity of the hydropower plants.

Tajikistan's Winter Energy Crisis: Electricity Supply and Demand Alternatives
http://dx.doi.org/10.1596/978-0-8213-9967-5

engineering design. These studies are scheduled to be completed in summer 2013, followed by riparian discussion and public consultation. The studies are one component in assessing the viability of the proposed project as a contribution to Tajikistan's energy security.

Given the Rogun studies are ongoing and considering that, based on global experience, such large and complex hydropower projects, even if they are deemed technically and economically feasible, are subject to long preparation times and delays, the study includes neither Rogun nor any of large (seasonal) storage projects.[3] Rather, the Tajikistan Winter Energy Crisis Study was undertaken in parallel to the Rogun Assessment Studies.

Table 3.1 describes the list of proposed hydropower projects considered in the study.

Current HPPs in operation are located on Vakhsh/Zaravshon Rivers. Construction of plants in new areas requires expansion of the transmission system to connect the plants with the existing grid. This is an issue especially for the plants on the Pyanj River, which are geographically remote from the grid.

Investment costs, where not available from existing studies, are based on available data on plants recently developed and constructed in Tajikistan. For run-of-river (ROR) plants, costs are estimated at US$1,800 per kW and US$2,000 per kW depending on their size.

Thermal Power Plants

Thermal power plants (TPPs) have a clear advantage with regard to provision of firm energy as they are not subject to seasonal hydrologic variability. Thermal power plants operate independently of seasonal variation so that firm capacity is equal to the installed capacity. Thermal power plants can become operational faster, provided that the linked fuel reserves are ready to be exploited. At present, thermal power plants play only a minor role in the Tajik system. With virtually no domestic production of natural gas, thermal power plants are dependent on coal.

Coal

Based on previous studies, there are at least three coal mines that could be used for fuel supply in the near future: Ziddy, Shurob, and Fon Yaghnob. These mines have estimated proven reserves of around 500 million tons and could supply four new plants totaling 1,300 MW of capacity (Dushanbe-2, Shurob-1 and –2, and Fon Yaghnob) (see table 3.2).

These plants are included in the GoT's priority list to add much-needed firm capacity and support self-sufficiency. Dushanbe-2 is planned to be commissioned in phases. The first 50 MW is expected by winter of 2013, with an additional 50 MW the following year. The final 100 MW is subject to satisfactory operation and confirmation of compliance to environmental safeguards/policies, but could be in place in 2016. Shurob-1 could be commissioned in 2018. These plants

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Table 3.1 Key Data of Identified HPP Supply Alternatives (Excluding Storage Projects)

			Installed Capacity	*Firm Capacity*	*Avg Generation*	*Earliest Date*	*Investm. Cost* [a]	*Unit Cost* [b]
Name	*River*	*Type*	*MW*	*MW*	*GWh/yr*	*Year*	*US$ millions*	*cents/kWh*
Shurob HPP	Vakhsh	ROR	850	99	3,043	2020	1,565	25.5
Fandarya	Zaravshon	ROR	160	14	497	2020	327	36.2
Sangiston	Zaravshon	ROR	140	27	647	2020	292	17.1
Aynin	Zaravshon	ROR	160	30	729	2020	330	17.3
Yavan	Zaravshon	ROR	160	25	664	2020	331	21.0
Dupulin	Zaravshon	ROR	90	10	319	2020	190	30.0
Barshor	Pyanj	ROR	300	28	763	2025	619	35.5
Anderob	Pyanj	ROR	650	58	1,577	2025	1,291	35.9
Pish	Pyanj	ROR	320	87	1,629	2025	655	12.0
Sanobod	Pyanj	ROR	125	125	1,088	2020	285	3.5
Yzgulem	Pyanj	ROR	850	139	3,318	2025	1,662	19.2
Granit gates	Pyanj	ROR	2,100	436	9,364	2028	4,020	17.1
Shirgovat	Pyanj	ROR	1,900	300	7,272	2026	3,659	20.7
Hostav	Pyanj	ROR	1,200	456	7,122	2026	2,309	8.6
Jumar	Pyanj	ROR	2,000	420	8,970	2026	3,769	15.2
Moskov	Pyanj	ROR	800	429	5,640	2025	1,501	5.6
Kokcha	Pyanj	ROR	350	82	1,664	2025	691	13.4
Urfatin	Obi-Hingou	ROR	160	48	940	2022	349	11.3
Shtien	Obi-Hingou	ROR	160	54	985	2022	349	10.0
Nurabad-2	Obi-Hingou	ROR	120	38	723	2020	270	10.9
Nurabad-1	Obi-Hingou	ROR	150	40	847	2021	310	12.0
Garms	Surkhob	ROR	120	46	737	2022	249	8.4
SHPPs	Various	ROR	35	7	175	2015	110	22.2

Source: World Bank data.

Notes: GWh = gigawatt hour; kWh = kilowatt hour; MW = megawatt; ROR = run-of-river; SHPPs = small hydropower promotion projects.

a. Including transmission tie-in and resettlement/environmental mitigation costs, but excluding interest during construction

b. Unit cost of firm energy: takes into consideration investment costs including interest during construction, operation and maintenance costs, fuel costs, costs of tie-in to the nearest transmission grid, and environmental mitigation costs. The total costs over the lifetime of the project are converted into an annual value (annuity) and then set in relation to the annual firm energy. Firm energy generation values are available in appendix E.

Table 3.2 Key Data of Thermal Supply Options

Name	Fuel	Type	*Firm Capacity* MW	*Installed Capacity* MW	*Winter Energy* GWh	*Earliest Date on Line* Year	*Investment Cost*[a] US$ millions	*Unit Cost of Firm Energy*[b] cents/kWh
Dushanbe-2	Coal	TPP	200	200	1000	2013–16	349	8.7
Shurob-1 TPP	Coal	TPP	300	300	1,104	2018	523	9.9
Shurob-2 TPP	Coal	TPP	300	300	1,104	2020	523	9.9
Fon Yaghnob	Coal	TPP	500	500	1,840	2020	1,051	11.2
Emergency diesel	Diesel	TPP	100	100	396	2014	40	28.8

Source: World Bank data.
Notes: GWh = gigawatt hour; kWh = kilowatt hour; MW = megawatt; TPP = Thermal power plants.
a. Including transmission tie-in and resettlement/environmental mitigation costs, but excluding interest during construction
b. Unit cost of firm energy takes into consideration investment costs including interest during construction, operation and maintenance costs, fuel costs, costs of tie-in to the nearest transmission grid, and environmental mitigation costs. The total costs over the lifetime of the project are converted into an annual value (annuity) and then set in relation to the annual firm energy. Dushanbe-2 and Shurob TPPs are based on feasibility or prefeasibility studies produced by Chinese firms; Fon Yaghnob applies standards and costs in line with international practice.

would offset the retirement of Dushanbe-1 in 2018, adding 378 MW to the system.[4] With an accelerated program, an additional 300 MW could be added as Shurob-2 in 2020. The coal supply for a fourth coal power plant, Fon Yaghnob, has been confirmed and a feasibility study for a 500 MW plant is being discussed. If that study proceeds quickly, and financing for the plant secured, the Fon Yaghnob plant could be on line in by 2020, or earlier.

The costs of coal-fired generation range from 8.7 cents per kWh (Dushanbe-2) to 11.2 centers per kWh (Fon Yaghnob). These costs are based on the cost of hard coal of US$100 per ton. Investment costs vary between US$1,750 per kW and US$2,000 per kW, due in part to technology and construction assumptions: Dushanbe-2 and Shurob-1 assumptions were based on pre-feasibility and feasibility studies prepared by Chinese companies; Fon Yaghnob investment cost estimates are based on the recent average investment costs globally.[5] It should be noted that with modest incremental investment, the government could also consider building dual-fired thermal plants run on both coal and gas. If gas becomes available, operating costs could be decreased as a result.

Natural Gas

Natural gas offers a superior fuel for thermal generation. Combined-Cycle Gas Turbine (CCGT) plants have lower environmental impacts than coal-fired plants and can be built close to urban centers. At current gas import prices, the economic cost of gas-fired generation is estimated not to exceed 8 cents per kWh[6] compared to 8.7–11.2 c per kWh for coal-fired plants. Gaining access to domestic sources of natural gas could be a “game-changer” for Tajikistan by substituting both coal and imports. Designing coal-fired plants to have dual-fired

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coal/gas options is recommended to accommodate new sources of domestic or imported gas.

At present there are no known, commercially viable reserves of natural gas in Tajikistan. Some prospecting is underway, offering speculative but interesting survey results. For example, the Tethys oil and gas exploration company operating in the Bokhtar Production Sharing Contract area covering some 35,000 square meters has estimated gross unrisked mean recoverable resources of 27.5 billion barrels of oil equivalent (3.2 trillion cubic meters of gas and 8.5 billion barrels of oil and condensate). Gazprom is doing exploratory work at four sites, having reached about half of the target drill-bit depth. The United States Geological Survey (USGS), with assistance from the Afghan Geological Survey and the US Trade and Development Agency, undertook a 2006 energy survey resulting in the first-ever assessment of undiscovered Afghan oil and natural gas resources. The survey estimated that the reserves situated in the north of the country (at the Amu Darya Basin to the northwest and the Afghan-Tajik Basin to the northeast) could potentially contain exploitable reserves of 1.596 billion barrels of oil and over 1 trillion cubic meters of natural gas, 18 times the oil and triple the natural gas resources previously estimated. Although encouraging, these findings are based on preliminary investigations. For example, the Tethys estimate is based on a 2-dimensional seismic analysis, including an independent review, but no exploratory wells have been drilled. Considerably more detailed assessment of the technical and commercial viability of these sites is required to consider investment in new domestic gas-fired power plants.

Diesel

Emergency Diesel plants can be mobilized at short notice on a rental basis. However, due to their high costs (almost 29 cents per kWh), they are practical only as a stop-gap alternative for critical demand centers as the cost of supply is roughly four times the estimated average willingness to pay.

Imports

Tajikistan used to be part of the Central Asia Power System with a number of interconnections to its neighbors Uzbekistan and Kyrgyz Republic and, through Uzbekistan, to Turkmenistan. With low cost gas-fired power plants, the tariff for imported electricity would be around 6 cents per kWh. Various import routes are considered:

- Electricity imports directly from Uzbekistan
- Electricity imports from Turkmenistan through Uzbekistan
- Electricity imports from Turkmenistan through Afghanistan
- Natural gas imports from Uzbekistan and Turkmenistan for gas-fired plants (CCGTs) in Tajikistan.

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Electricity Imports from Uzbekistan

At present, most of the 220 kilovolts transmission lines connecting Tajikistan with Uzbekistan are currently switched off for various reasons, such as the government objectives of achieving energy independence and preventing unscheduled power flow. Currently there are no power flows between the two countries.

The major interconnection between Tajikistan and Uzbekistan is the link between Regar substation in the Region of Republican Subordination (RRS) region of Tajikistan to Surkhan and Guzar substations in Uzbekistan. The two 500 kilovolts lines were used for importing around 1,500 GWh annually during the winter season. A temporary bypass of the Regar substation between the Guzar and Surkhan line was constructed on Uzbek territory. Technically, the Regar-Surkhan line could be made operational again at negligible cost. The capacity of the line is sufficient for importing up to 950 MW (about 4,000 GWh) on a 500 kilovolts line.[7]

The possibility of imports from Uzbekistan is limited by difficult political and commercial obstacles. Notwithstanding, the GoT, through Barki Tajik and the Ministry of Energy and Industry, maintains dialogue with the Coordination Energy Council of Central Asia to consider opportunities for reunification of the Central Asia Power System to increase imports in the short term. Further effort by all parties will be needed to reinvigorate trade.

It is also recognized that imports from Uzbekistan in the future may be limited by available generating capacity. With increasing domestic demand and a number of power plants to be retired over the next few years, Uzbekistan is not expected to have surplus capacity in the winter. Nevertheless, some firm capacity (250 MW) may be made available in 2014 and 2015 after new power plants are commissioned in Uzbekistan, but likely will be restricted thereafter. An additional 300 MW could be available during low (off-peak) demand hours of the day. This could save water in the reservoirs in Tajikistan, to be used in peak hours to provide additional firm capacity equivalent. Moreover, it should be noted that

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Box 3.2 Benefits of Energy Trade

Studies have estimated the benefits of energy trade in Central Asia to be US$2 billion over three years. The economic benefit derives from savings that could be achieved through the following: (1) decreased use of primary energy resources (primarily gas and coal) by avoiding the wastage of hydropower energy; (2) balanced hydro/thermal generation mix, due to better opportunities for flexibility in dispatch; (3) decreased demand because of the diversification of demand (peak hours occur at different times in different countries); (4) joint operation due to greater use of renewable energy and decreasing environmental impact; (5) security of supply increases; (6) decreased need for investment due to improved system reliability; and (7) the ability to develop larger projects to achieve economies of scale.

Source: Mercados Energy Markets International 2010.

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electricity imports from Uzbekistan might be limited due to existing gas export contracts. Specifically, the available information on Uzbekistan's gas export contracts suggests that the projected gas production will be sufficient to meet domestic demand and honor export commitments, but data on quantities available for generating electricity for export purposes are needed.[8]

The major barrier to trade is establishing an agreeable framework for imports and exports and overcoming the political constraints to effective trade relations. Commercial concerns include uncontrolled power flows, poor payment discipline, and pricing. These can be partially addressed in contract design.[9] However, more fundamental issues of trade between the two countries—and indeed among all Central Asia countries—will require time and concerted effort to resolve. Overall, the Central Asia Power System (CAPS) lack mechanisms to monitor, discipline, and manage power flows. Price-based markets are in their infancy and concepts that realize trade benefits, such as time-of-day pricing, value of ancillary services, and requirements for reserve margins are not integrated into investment or operations planning. These difficulties are overlaid with a political reluctance to engage in open trade.

Notwithstanding the political barriers, resumption of trade could yield significant regional benefits. Two recent studies by the World Bank and the ADB concluded that increased electricity trade within Central Asia could save up to US$2 billion over three years, with negligible investments.

Revitalization of power exchange and synchronous operations across borders would enable imports to Tajikistan during winter from countries in which thermal power predominates (Uzbekistan and Turkmenistan) and export of the surplus from Tajikistan's hydro-dominated system in summer. Benefits to Tajikistan would accrue in terms of reducing winter shortages, increasing foreign exchange earnings, while all Central Asia countries would also benefit from stabilizing the power system, fuel cost savings, and lower electricity costs in summer (box 3.2).

Prior to achieving full and open markets among the Central Asian countries, gradual steps could be taken in establishing small, controlled trade to build trust and trade experience under modern commercial terms. For example, to avoid the problem of supply-demand imbalances by Tajikistan, concluded Power Purchase Agreement (PPAs) could form the basis of specific, manageable trade of specific quantities. A well-structured PPA would specify a payment scheme possibly including an escrow account or letter of credit. The supply itself could be from one of the nearby thermal plants in Northern Uzbekistan, electrically isolating it and connecting to loads in Tajikistan.

Electricity Imports from Turkmenistan through Uzbekistan

Tajikistan and Uzbekistan had established contracts for supply for several years; however, an acceptable arrangement for transiting ("wheeling") electricity through Uzbekistan could not be agreed.

Tapping Turkmenistan's extensive gas reserves for power generation and export would revitalize these past efforts to contract Turkmen-Tajik energy trade through existing lines. However, there is little reliable information on the supply

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situation in Turkmenistan. Some immediate supply constraints have been identified,[10] although approximately 100 MW is assumed to become available by 2015 based on the country's announced investment program. In the longer term, Turkmenistan has abundant gas reserves to supply additional plants for electricity export, should trade conditions be favorable.

Although transmission lines exist, Turkmenistan is no longer synchronized with the Central Asia grid. Islanded operations are possible but would require a two-part arrangement through Uzbekistan whereby Turkmenistan and Uzbekistan trade on the condition that an equal trade occurs between Uzbekistan and Tajikistan. With a PPA-based contract between Turkmenistan and Tajikistan, a back-to-back High Voltage Direct Current (HVDC) convertor station could be built on the Turkmen border to supply power to Uzbekistan asynchronously. This has worked successfully in other countries in the Europe and Central Asia (ECA) Region (for example, back-to-back HVDC convertor stations were planned for Georgian power exports to Turkey).

Electricity Imports from Turkmenistan through Afghanistan

The transmission line via Afghanistan (Andkhoy, Pul-e-Khumri) could provide an alternative or additional route for electricity imports to Tajikistan. This supply option depends on the timely availability of the transmission infrastructure in Afghanistan and the construction of one or more gas-fired plants in Turkmenistan specifically for electricity export. The most immediate and lower-cost option is to combine with current efforts to expand the Turkmenistan-Afghanistan trade infrastructure, an approach that would require some new investments and coordination with the Turkmen-Afghan project but could provide 150 MW. A new Turkmenistan-Afghanistan-Tajikistan line, as presented at the Regional Economic Cooperation Conference on Afghanistan (RECCA) meeting in Dushanbe in March, 2012, could provide an additional 300 MW dedicated to Tajikistan. Although electricity generation in combined cycle plants is expected to be a low cost thermal option, the cost of transmission infrastructure and the lack of a market for the summer energy may push the import tariff of this dedicated line to relatively high levels.

Table 3.3 summarizes the possible alternatives for electricity imports. Only 300 MW is likely to be available immediately with an additional 100 MW by 2015 from new capacity in Turkmenistan. Temporary supply of 250 MW in 2014 could be available from Uzbekistan. However, given uncertainty with capacity situation, these imports are expected to gradually phase out by 2019. New Turkmen plants and transmission lines through Afghanistan could expand supply by 450 MW by 2018/19.

In the longer term, as Central Asia integrates more with South Asia, and the Chinese markets stimulate energy development, alternative opportunities for both Tajik imports and exports could be pursued. Expanded linkages to the Russian Federation in the north, China in the south and east, and the Islamic Republic of Iran in the west would diversify trade, mitigate risk, and expand opportunities to share hydropower benefits to a wider mixed energy system. This

Tajikistan's Winter Energy Crisis: Electricity Supply and Demand Alternatives
http://dx.doi.org/10.1596/978-0-8213-9967-5

Table 3.3 Key Data of Import Supply Alternatives

Name	Type	Installed Capacity MW	Winter Energy GWh	Earliest Date on Year	Investment Cost[a] US$ millions	Estimated Unit Cost[b] cents /kWh
Import Uzbekistan to Regar	IMP	300	400	2013	0	6.0
Import Uzbekistan to Regar	IMP	250	450	2014/15[c]	0	6.0
Import Turkmenistan to Regar	IMP	100	400	2015	0	6.0
Import Turkmenistan via Afghanistan	IMP	150	570	2018	0	11.8
Import Turkmenistan via Afghanistan	IMP	300	1,140	2019	0	11.8

Source: World Bank data.
Note: GWh = gigawatt hour; IMP = import; kWh = kilowatt hour; MW = megawatt.
a. Including transmission tie-in and resettlement/environmental mitigation costs, but excluding interest during construction
b. Unit cost of firm energy takes into consideration investment costs including interest during construction, operation and maintenance costs, fuel costs, costs of tie-in to the nearest transmission grid, and environmental mitigation costs. Assumes an international price of natural gas of US$250/tcm
c. Assumed to decline to 0 by 2019.

is a long-term vision, necessitating considerable development of energy markets and interconnections, but is increasingly possible with interconnections with the Republic of Kyrgyz, increasingly sophisticated energy management and investment by Kazakhstan, and greater economic integration with Afghanistan and Turkmenistan.

Imports of Natural Gas

Currently, the only source of natural gas to Tajikistan is imports. In 2011, the country imported only 180 million cubic meters of natural gas compared to an average of 600–700 million cubic meters in 2000–07. The total capacity of the gas trunk lines is over 7 billion cubic meters, leaving considerable unutilized pipeline capacity. This spare capacity could fuel a 450 MW CCGT. Assuming an international price for the fuel, the estimated cost of building and operating natural gas-fired generators in Tajikistan is less than 8 c per kWh, among the lowest cost options for Tajikistan.

Both Turkmenistan and Uzbekistan have significant reserves of natural gas. Uzbekistan has recently committed to long-term contracts with China and has indicated a policy goal to increase exports to 30 bcm by 2014, even substituting coal for domestic electricity production to increase available natural gas supply for export. However, the immediate availability of natural gas is not clear; Uzbekistan indicated a supply constraint when ending a contract with Tajikistan in April 2012.

One of the primary barriers to the resumption of gas supplies to Tajikistan is acceptable commercial provisions. Given past difficulties, commercial risks for both Tajikistan and Uzbekistan related to payments and delivery would have to be addressed through enforceable contract provisions on a price based on

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international prices (export value) for gas. The willingness and prudence of investing in new CCGTs in Tajikistan would depend on the reliability of gas imports.

Nonhydro Renewable Energy (RE)

As part of an analysis undertaken during earlier stages of the study, various RE technologies were assessed with regard to potential short to medium-term development in Tajikistan. The results of this assessment are as follows:

- **Wind Energy:** Based on existing studies and assessments of wind energy in Tajikistan, the potential for viable power plants is limited. Sites with average wind speeds of 5 meters per second or higher are typically located in remote and mountainous areas where grid connection cannot be realized at reasonable costs. Wind energy is therefore considered as a technology for decentralized solutions, operating in island mode and supported by energy storage. For the purposes of this study, wind power is not considered as a significant potential supply alternative. However, it is recommended to assess the feasibility of pursuing development of off-grid wind energy to power remote rural areas.
- **Solar Energy** (for electricity production): With regard to solar power, photovoltaic (PV) power is considered a potential option that can be further developed in Tajikistan, whose climate conditions are favorable. Solar irradiation is especially high in mountainous regions. The country's potential is estimated at about 25 billion kWh per year. However, PV cannot provide any firm capacity without storage and has only a limited positive influence on the winter deficit due to low irradiation during this season. Generally, in the context of power system planning, solar power has the primary role of saving energy since you can't rely on its availability. Because fuel in the form of gas, oil, or coal plays only a very minor role in Tajikistan, solar power is not considered as a priority supply option. Nevertheless, since solar PV is technically feasible, it was considered as a supply option with the following technical parameters:
  - Installed capacity: 50 MW (allocated over five sites)
  - Firm capacity: 0 MW
  - Average annual energy: 77 GWh
  - Earliest date: 2015
  - Capital expenditure: US$152 million
  - Unit costs: 64 cent per kWh (based on energy available in winter).

Other technologies like geothermal or waste-to-energy are only of limited potential and prohibitive cost. Independent consultants view waste-to-energy to be much too expensive for Tajikistan in the near- to midterm. Prospects for geothermal energy are unclear. However, given the geology specifics of the country, the GoT may consider conducting surface studies to identify prospective geothermal sites, which could support geothermal power plants.

http://dx.doi.org/10.1596/978-0-8213-9967-5

Notes

1. This figure includes the effect of sedimentation at Nurek, but does not include the impact of increased capacity from upgrading during rehabilitation at any plant.
2. The Sangtuda plant, located on the Vakhsh cascade, is treated as a committed plant and so is included in the estimate of existing supply.
3. In addition to Rogun, the following projects were eliminated from consideration: Dashtijum on the Pyanj River on the border with Afghanistan (estimated installed capacity of 4,000 MW); Sangvor (160 MW on the Obi-Hingou River); and Oburdon (120 MW on the Zaravshon River). None of these three identified projects have recent feasibility studies.
4. The GoT has targeted Dushanbe-1 for retirement in 2015, to align with the expected commissioning date for Dushanbe-2. However, given the risk of delay, as well as the severity of the shortages, the analysis assumes continued emergency maintenance will extend retirement until 2018.
5. A feasibility study is under consideration at a cost of US$1.2 million.
6. Assuming gas export price of US$250 per tcm if gas reserves are discovered in Tajikistan.
7. Additional 220 kV lines in the north have an additional capacity of 450 MW.
8. World Bank analysis.
9. See box B.3 in appendix B.
10. Fichtner Consultants, Pers. Communication, August 2012.

Tajikistan’s Winter Energy Crisis: Electricity Supply and Demand Alternatives
http://dx.doi.org/10.1596/978-0-8213-9967-5

CHAPTER 4

Targeting Energy Shortages

The immediate focus of energy development in Tajikistan is to eliminate the current winter energy deficit. Estimated at about 24 percent of winter demand, it results in both social and economic harm. The impact of this deficit is not predictable as both demand for electricity and supply of water for hydropower vary with weather conditions. Winter energy shortages, estimated at 2,700 GWh in 2012, could exceed 6,800 GWh by 2020.

Based on demand- and supply-side measures identified in chapters 2 and 3, this chapter identifies a package or portfolio of energy efficiency and supply alternatives to eliminate the deficit. Alternatives are selected to meet peak winter energy demand at least cost among the identified set of possible alternatives: that is the combination of alternatives that minimizes investment and operating costs while accounting for export revenues.[1]

A plan to meet demand to 2020 is described in the section entitled "Alternatives to the Year 2020," showing the time and sources needed to eliminate the current deficit. Additional actions that could accelerate the reduction in deficits are also discussed. The costs, affordability, and financeability of eliminating the deficit are covered in the section entitled "Costs, Affordability, and Financeability," while challenges and opportunities are addressed in the similarly titled section.

Alternatives to the Year 2020

There is no one solution for Tajikistan's winter electricity deficit. A multipronged approach encompassing comprehensive energy efficiency, and pricing program, rapid development of thermal plants, and revitalization and expansion of imports could, however, bring energy demand and supply close to balance by 2016. The specifics of the short-term actions required are given in table 4.1.

As shown, savings from energy efficiency, fuel switching, and a tariff increase can make the most pronounced contribution to energy security, reducing winter demand by 1,635 GWh per year, or about 40 percent of the expected deficit in 2016 (in the absence of any measures). Part of this is some 418 GWh per year

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Table 4.1 Measures to Meet Energy Demand to 2020

Category	*Supply Alternative*	*Additions to Capacity at 2020*	*Additions to Winter Energy (GWh) at 2020*	*Date of Service*	*Investment Cost to 2020 (US$ millions)*	*Levelized Cost (cents/kWh)*
Energy efficiency/fuel switching	Tariff increases, T&D loss reduction, demand efficiencies, load mngmt, fuel switching	**1,108 MW**	**3,250**	**beginning 2014**	**280**	**<1 as a group**
New supply	Dushanbe-2 TPP	200 MW	1,000	2013–16	349	8.7
	Shurob-1 TPP	300 MW	1,104	2018	523	9.9
	Shurob-2 TPP	300 MW	1,104	2020	523	9.9
	Sanobod RoR HPP	125 MW	539	2020	285	3.5
	Subtotal	**925 MW**	**3,747**	**2020**	**1,680**	
Imports	Additional CAPS imports[a]	100 MW	400	2013	Included in unit cost	6.0
		100 MW	400	2015		6.0
	Imports from Turkmenistan	150 MW	570	2018		11.8
		300 MW	1,140	2019		11.8
	Subtotal	**650 MW**	**2,510**	**2019**		
Transmission for exports					**360**	n.a.
Rehabilitation		Included in existing supply			**1,105**	
Total		**2,683 MW**	**9,507 GWh**		**US$3,425**	

Source: World Bank data.

Note: CAPS = Central Asia Power System; GWh = gigawatt hour; HPP = Hydropower plant; kWh = kilowatt hour; MW = megawatt; n.a. = not applicable; RoR = Run-of-river; TPP = Thermal Power Plant.

a. An additional 250 MW is assumed to be available from Uzbekistan in 2014 and 2015 only and then phasing out by 2019.

of potential savings, during winter, and another 150 GWh per year from shifting maintenance from winter to summer at Tajik Aluminum Company (TALCO) by 2016. New domestic supply—a 200 MW generating plant—contributes about 1,000 GWh per year (24 percent) and imports from Central Asia Power System (CAPS) and Turkmenistan through Afghanistan offer another 1,550 GWh per year (37 percent) by 2016.

Table 4.2 compares the additions to supply and moderation of demand against energy shortages. As shown, the earliest solutions are imports and ongoing savings from EEPs and initial conversions to coal-based heating systems. These two sources remain the only contributions to reducing shortages until 2016 when the first coal-fired plant is scheduled to become operational.

Additional measures could be taken to further accelerate the management of the energy shortages. These alternatives bring an added level of uncertainty or risk and would need further detailed examination.

- **More ambitious energy efficiency measures:** A larger reduction of winter electricity demand may be achievable if the GoT: (1) sets higher targets for coal-based heating (80 percent instead of 65 percent under "base-case") and accelerates the penetration rate of coal-fired District Heating (DH) system; and (2) aggressively promotes residential building insulation (40 percent of buildings instead of 30 percent under the "base-case" scenario). This accelerated EEP would reduce the winter demand by an additional 1 percent, or 110 GWh by 2020.
- **Seasonal energy management at the TALCO aluminum plant:** Careful scheduling of repair and maintenance within the TALCO smelting process could yield a considerable near-term boost to winter energy supply. The electrolysis process used in aluminum smelting runs continuously, with cells being disconnected, repaired, and returned to the production site as quickly as possible. Major repairs of the cells take three to four months, with several cells under repair simultaneously. It is technically possible to schedule the major repair of cells during winter periods, resulting in more cells being active in summer period and fewer in winter. In addition, it is also technically possible to reduce the amperage in winter without damage to an aluminum cell to reduce energy consumption. If aluminum manufacturers are forced to reduce their power consumption, an international practice is to reduce cell amperage, as experienced by Russian manufacturers in the 1990s. Low aluminum prices have resulted in a curtailment of energy use in aluminum smelters in the recent past while some have gone as far as reducing or shutting production (box 4.1).

  Such management options are not without risk. Repairs require a suitable location for storage of disabled cells and start-up needs to be carefully based on local climate and other plant energy needs. Qualified personnel are needed to ensure that the quality of the repair is not compromised from restoring cells in bulk at the end of the winter season. To reduce amperage, the entire

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Table 4.2 Eliminating Winter Shortages

			2012	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*
Deficit without measures (incl. rehab upgrades)		GWh	2,700	3,170	3,640	4,100	4,510	5,000	5,410	6,300	6,800
Measures to reduce deficit											
Energy efficiency	Tariff increase	GWh	0	30	102	276	464	665	877	1,101	1,339
	T&D Loss reduction	GWh	13	96	186	295	409	498	586	677	771
	TALCO EE	GWh	0	0	0	359	418	475	531	531	531
	Demand management	GWh	0	0	7	14	22	41	61	82	102
TALCO maintenance program	Increased maintenance in winter	GWh	0	0	150	150	150	150	150	150	150
Fuel switching[a]	From gas to coal fired	GWh	0	44	88	130	172	214	255	296	357
New generation	Thermal	GWh	0	250	500	500	1,000	1,000	2,104	2,104	3,208
	Hydropower	GWh	0	0	0	0	0	0	0	0	539
Imports[a]	Uzbekistan	GWh	0	400	1,400	1,400	1,150	900	650	400	400
	Turkmenistan	GWh	0	0	0	400	400	400	970	2,110	2,110
Deficit after measures		**GWh**	**2,690**	**2,350**	**1,210**	**580**	**320**	**660**	**–770**	**–1,150**	**–2,710**

Source: World Bank data.
Note: GWh = gigawatt hour; TALCO = Tajik Aluminum Company.
a. The coal-fired plant and imports are assumed to operate base-loaded for 6 months, and 50 percent of the time for 2 months, for a total of 5,000 hours/year.

Box 4.1 Global Aluminum Industry—Recent Trends

The global aluminum industry is facing a continued trend of low prices in the recent years. Aluminum prices have been an exception in the recovering commodity market world over. The global aluminum market was estimated to be oversupplied by 1.6 million tons last year, keeping prices below 2,000 US$/metric ton (MT). The reduced demand and increased production in China, growing from 2.8 million MT in the year 2000 to 17.8 million MT in 2011 is considered to be the major contributing factor to this trend. TALCO produced 280,000 MT in 2011.

Several international aluminum companies have started responding to this low-price situation by adopting different strategies. Rusal has curtailed production by 150,000 MT in 2012; Alcoa has closed smelters in Italy and Spain; Rio Tinto closed its Lynemouth smelter in the United Kingdom; Norsk Hydro mothballed its smelter in Austria; Klesch shut down production in Netherlands; Bosnia's Aluminij Mostar announced a 12.5 percent production cut; Ormet plans to close six potlines in the United States and may close more depending on electricity price negotiation results.

China has upgraded the energy efficiency of their production with pots operating at 500,000 amps compared to 300,000 amps at Rusal's newest smelter. Ghana has responded to low aluminum prices by operating only one of the five pot lines at its VALCO aluminum smelter.

TALCO may wish to consider taking similar steps. Its equipment is old and inefficient and could decrease energy use by about 1,180 GWh per year by implementing energy efficiency measures. Taking pot lines off the production, during the winter, while aluminum prices are low would minimize the negative impact of lost production. Further, during the winter when power supply can't keep up with demand, it would provide benefits to others consumers in Tajikistan by reduced load shedding. A win-win-win situation may be available for Tajikistan with TALCO improving efficiency and future profitability; minimizing load shedding and reducing the load shedding problem.

energy balance of the cells has to be recalculated and managed within the cells to avoid operation being impeded and replacement of nodes prevented. Overall the process for reducing amperage is laborious and requires considerable preparation. In both cases of winter energy conservation, overall production could be affected with consequences for costs and revenues. This would have obvious social implications for the large workforce who depend on the plant for livelihoods and economic stability.

However, implemented as quickly as possible, these measures could provide one of the few opportunities to significantly reduce deficits in the next few winters, while new supplies are being developed. A detailed engineering and economic assessment, which is beyond the scope of this study, would be needed to better assess the feasibility, risks, and benefits/costs of such an approach.

Tajikistan's Winter Energy Crisis: Electricity Supply and Demand Alternatives
http://dx.doi.org/10.1596/978-0-8213-9967-5

- **Increased capacity upgrades during rehabilitation:** Rehabilitation assumes a modest 2.5–5 percent increase in plant capacity from technological upgrades. Industry experience ranges from below 2.55 to above 15 percent. For example, the GoT is aiming to increase capacity of Nurek by 360–400 MW (over 10 percent). However, potential capacity upgrades are highly dependent on site and technology specifics of each unit and each plant, and it is difficult to predict in the absence of detailed feasibility studies. If it is possible to double the capacity add-on, an additional 260 GWh would be available from the existing hydropower system.
- **Secured access to natural gas**: Imports are currently about 25 percent of the average gas imports over 2000–07, leaving considerable pipeline capacity for imports to Tajikistan. A reliable source of natural gas could justify new Combined-Cycle Gas Turbine (CCGT) plants in Tajikistan which can be built quickly and at low cost. The spare capacity could fuel a 450-MW CCGT (adding over 2,000 GWh), eliminating more expensive supply additions such as imports from Turkmenistan through Afghanistan and Shurob Thermal Power Plant (TPP) in 2018 and 2020, respectively. Gas supplies could also fuel district heating systems. Based on recent experience, the willingness and prudence of investing in new CCGTs in Tajikistan would depend on the reliability of gas imports. More detailed assessments of gas supply in Uzbekistan and Turkmenistan are required.
- **Small Hydropower plants (HPPs) and diesel generators:** The package of small HPP could be operational within a few years. However, they contribute very marginally to firm capacity (7 MW) and at high cost (22 cents per kWh) due to their size and flow constraints in winter. Stand-alone diesel generators could be leased to operate as a temporary solution for highest-risk customers like hospitals. However, it is also a very expensive solution at over 28 cents per kWh and contributes to pollution. Although they have negligible effect on eliminating the deficit, small HPPs and diesel generators may be relevant in specific circumstances (isolated communities, specific buildings), as part of a load management program.
- **Expanded imports of electricity**: As noted above, there is significant capacity on the transmission line from CAPS to Tajikistan. The base analysis assumes only 200–450 MW are taken up, given uncertainty about the construction of new capacity in Uzbekistan and Turkmenistan. With clear and immediate trade discussions, including terms of contracts for generation and transmitting power, it may be possible to add additional CCGT generating capacity to more fully use the existing 950 MW line.

A Diversified Electricity Sector

Expanding imports of natural gas and electricity and investing in coal power plants could profoundly change the structure of the power sector in Tajikistan. The addition of 1,450 MW of thermal resources by 2020 (925 MW domestic thermal-fired generation and 650 MW from imports) will secure reliable winter power, help balance the variability of the existing hydropower system, and

Tajikistan's Winter Energy Crisis: Electricity Supply and Demand Alternatives
http://dx.doi.org/10.1596/978-0-8213-9967-5

introduce possible system optimization between thermal and hydro services for further system stability and cost savings. As a consequence, the share of domestic thermal could increase to almost 20 percent, as could imports. With no significant additions, hydropower would decline to about 60 percent of firm capacity.[2]

Costs, Affordability, and Financeability

Economic Cost of Meeting Power Demand

The economic cost of meeting the projected demand for power covers both the demand-side measures and additions to power supply that are discussed in the previous chapters. The demand-side measures cover investment in reduction of T&D energy losses and in end-use efficiency improvements.[3] Figure 2.3 shows the projected impacts of demand-side measures on power demand. The costs of additions to supply capacity cover the following categories: investment in new generation capacity, rehabilitation of existing power supply facilities needed to maintain output from them, operating and maintenance of generation capacity and of the transmission and distribution networks, fuel consumption for generation, and environmental impacts of power generation. For the purposes of this study to examine possible solutions to Tajikistan's winter energy crises, environmental costs were not monetized and so not included in the estimation of economic cost. However, emissions are noted in natural units as part of the multicriteria analysis and further research would need to be conducted for the entire range of possible solutions.

The measure of economic cost of power in Tajikistan is the long-run average incremental cost (LRAIC) of meeting the projected growth in power demand from the long-run power development program selected to meet the economically efficient demand for power (see the section entitled "Current Demand for Electricity" in chapter 2). The term LRAIC is defined in box 4.2.

This estimate of economic cost of power is compared with the average tariff charged in 2012 of 2.25 cents per kWh. Hence the LRAIC has to be converted to the equivalent cost per kWh billed, taking into account technical losses in the Tajik power networks and incremental costs of operating, maintaining, and expanding the transmission and distribution networks.

Box 4.2 Definition of LRAIC of Power

LRAIC of meeting the projected growth in power demand is the ratio of (the discounted present value of the stream of incremental investment and O&M costs in demand-side measures and supply-side additions including rehabilitation costs and transmission investments) to (the discounted present value of the stream of incremental energy consumed under the forecast of power demand) . The discount period runs from (1) the first year of the planning period to the final year of the planning period; and (2) over a run-out period of 30 years starting in the year following the final year that captures the benefits of production from the full

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http://dx.doi.org/10.1596/978-0-8213-9967-5

Box 4.2 Definition of LRAIC of Power *(continued)*

working lives of the new power plants beyond the final year. The annual values used for the run-out period are the costs and energy values for the final year of the planning period.

The term “incremental” refers to the increase in the amount of energy supplied or costs incurred for the whole power system in a year during the planning period over the amount of energy supplied or costs incurred in the first year of the planning period.

The use of incremental costs reflects the principle of using only presently uncommitted costs and benefits in economic analysis. Past and presently firmly committed expenditures and benefits are excluded from this analysis. For economic analysis, the discount rate used is the estimated opportunity cost of capital to Tajikistan, assumed to be 10 percent.

Table 4.3 shows the derivation of the LRAIC under the approach for two scenarios. One of them excludes revenues from exports of surplus summertime hydroenergy because these exports are not yet occurring. The other scenario includes these projected export revenues to show the importance of export earnings to mitigating the cost to Tajik consumers and hence, its role in power development policy for Tajikistan. The resulting costs are 11.7 cents per kWh consumed excluding export revenues and 10.4 cents per kWh consumed including export revenues. The next section draws the implications of these values of LRAIC for cost recovery and affordability.

The values of these LRAIC estimates reflect the costs of new installed generating capacity among the existing expansion options in Tajikistan, which range around US$2,000 per kW of installed capacity. They also reflect the significant costs of rehabilitation and new transmission assets, neither of which adds significantly to incremental supply. These costs are moderated by the inclusion of demand-side measures, which produce energy savings at very low average costs.[4]

Affordability

The affordability of increased power supply is reflected in the difference between the economic cost of expanding power supply and electricity consumers’ willingness to pay (WTP) for more power over their present consumption levels. The weighted average value of 7 cents per kWh consumed, that is the estimated WTP by consumers for the projected amount of unserved power demand in the next few years, is nearly three times the current average tariff, but it is about 60 percent of the LRAIC excluding export revenues, and about 67 percent of the LRAIC including export revenues. This finding indicates that electricity tariffs can be raised substantially—possibly to cover as much as half of the economic cost of increasing power supply—within affordability constraints for consumers and in socially responsible ways. It also indicates that a substantial proportion—possibly up to a half—of this cost should be covered from other sources to derive economic benefits from expanding power consumption.

That the WTP analysis suggests customers may be willing to pay more for electricity is an important finding, providing the economic basis for a long-term

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Table 4.3 Derivation of LRAIC for Tajik Power Sector Development up to 2020

LRAIC Component	*Present Value @ 10% Excluding Export Revenues*	*Present Value @ 10% Including Export Revenues*
Incremental domestic energy supplied	44,862 GWh dispatched	44,862 GWh dispatched
Less: T&D losses[a]	4,787 GWh dispatched	4,787 GWh dispatched
Incremental domestic energy consumed	40,076 GWh consumed	40,076 GWh consumed
Incremental economic supply cost	US$3,679 million	US$3,679 million
Less: Incremental export revenues	—	US$746 million
Add: Export transmission investments	—	US$224 million
Net incremental supply cost	US$3,679 million	US$3,157 million
LRAIC before T&D costs	9.2 cents per kWh consumed[b]	7.9 cents per kWh consumed
Add: T&D invest.+ O&M	2.5 cents per kWh consumed	2.5 cents per kWh consumed
LRAIC	11.7 cents per kWh consumed	10.4 cents per kWh consumed

Source: World Bank data.
Notes: GWh = gigawatt hour; kWh= kilowatt hour; LRAIC = long-run average incremental cost; — = not available.
a. T&D losses = 10.7 percent of dispatched energy (=11.9 percent of consumed energy).
b. = 3,679/40,076.

tariff policy. The GoT increased tariffs during 2006–11 by 250 percent and followed by another 12 percent in 2012 (in Somoni terms). Although they do not provide for future investment, tariffs now approximate current variable costs of power supply. However, increasing tariffs in the current context of significant power shortages may seem paradoxical to consumers and may result in prompt negative public reaction. It is beyond the scope of this study to address tariff policy but a careful assessment of approaches to appropriate market signals and cost sharing should be a priority in the near future. Efforts should be made to combine tariff policy with other actions recommended in this study, including ambitious EEPs and improved quality of energy services. As previously noted, due care for vulnerable and low-income consumers will require adequate social safety nets as part of any tariff policy.

Even with some tariff reform, affordability raises the question of subsidies for power consumption, particularly who should receive them and who should provide them. It also raises the need to distinguish between subsidies in the economic sense and financial sense. The two differ substantially in concept. The analysis performed for this study can describe the economic subsidy that may be involved (the difference between costs covered by the tariff and the LRAIC), but it cannot produce meaningful estimates of financial subsidies.[5]

The Financing Challenge

Some form of compromise between economic principles and financial reality has to be found for financing the long-term expansion of Tajikistan's power supply.

This compromise will necessarily involve a package of measures that reduce power demand through improved supply efficiency and end-use efficiency, raise electricity tariffs, cut power supply costs through better planning and capacity selection, and improves cost recovery from consumers through improved commercial practices and better structured tariffs. A large financing shortfall is likely to persist in the current situation, however, even if and when all these economic measures have been fully exploited.

Table 4.4 summarizes the investment requirements for the next eight years to 2020. The requirements are expressed in 2012 US$ prices and omit cost inflation. They also omit interest during construction and Tajik taxes on goods and services used for these investments. They total about US$3.4 billion in these economic terms, and hence average about US$380 million per year. This financing "bill" is composed of new generating capacity (49 percent) and costs for rehabilitation of the existing system (32 percent), with the remainder (19 percent) covering EEPs and construction of transmission lines for power exports.

Despite the possibility of increased tariffs, much of the investment needs will have to be sourced from outside the power sector. Given that the investment climate is too weak to attract substantial private investment in this sector, the funds would have to be obtained against the GoT credit. Official financing agencies could be key providers of some of these funds.

To better understand the difficult challenge of mobilizing this scale of investment, the funding requirement is compared to the projected GDP, both terms expressed in constant dollars.[6] As shown in table 4.5, investment funds needed to finance power additions average 4.8 percent of projected GDP for the period 2012–20. Moreover, the proportions rise to high peaks in some years, notably to around 9 percent in 2016.

These are very high and prolonged rates for one sector of the economy. A financing plan will need to assess and nurture public-private partnerships, seek mechanisms to leverage limited budget funds, and coordinate with tariff policy and the allocation of mandates and responsibilities. Initiating and managing an investment program of this size will also require close attention to the

Table 4.4 Investment Funding Requirements from 2012 to 2020
2012 US$ millions

Year	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*Total*
New hydro generating capacity	0	0	0	0	43	100	86	57	0	285
New thermal generating capacity	121	140	87	183	209	314	209	131	0	1,395
Rehabilitate generating capacity	56	261	274	205	100	210	0	0	0	1,105
Reduce system energy losses	0	6	6	6	6	3	3	3	3	36
Investments in end-use efficiency	0	21	50	50	31	22	22	22	27	244
Transmission for power export	0	0	0	0	360	0	0	0	0	360
Total investment requirements	177	427	416	444	749	648	320	213	30	3,425

Source: World Bank data.

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Table 4.5 Investment Funding Requirements to Finance Power Additions from 2012 to 2020
2012 US$ millions[a]

Year	*2012*	*2013*	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*
Projected GDP growth rate (%)	7.0	7.2	7.3	6.0	6.0	6.0	5.0	5.0	5.0
Projected GDP ($)	6,379	6,838	7,337	7,777	8,244	8,739	9,176	9,634	10,116
Investment ($)	177	427	416	444	749	648	320	213	30
Investment as % of GDP	2.8	6.2	5.7	5.7	9.1	7.4	3.5	2.2	0.3

Source: World Bank data.
a. Excludes investment costs for new supply commissioned/demand measures implemented after 2020.

governance and capacity within Barki Tajik and the Ministry of Energy. For example, ongoing efforts to strengthen the management and fiduciary process within Barki Tajik will be key elements in creating and implementing the energy investment program.

The current electricity prices are roughly adequate to meet operating costs but are insufficient to provide funding for new investments. In other countries, well-run, financially sound power companies that are able to meet their investment needs finance about 40 percent of new investments from internal cash generation; the remainder is debt financed. With investment needs in the power sector of about US$380 million per year, internal cash generation from Barki Tajik would need to be about US$150 million per year. With sales (excluding TALCO) of about 14.5 terawatt hour per year, and commercial losses at 10 percent, electricity prices would need to increase by 1.0 cents per kWh to meet this target. The remaining gap of US$230 million per year of debt financing would also be a challenge, but could be met by donor or international financial institution (IFI) financing or supplier financing.

The financing of energy efficiency investments of about US$30 million per year is also challenging. Much of this should be commercially viable as the proposed energy efficiency investments at TALCO are estimated to have payback periods of less than 2½ years. Building level financing is more difficult and requires a comprehensive support plan and high-level government commitment to succeed. The EEP should start with low-cost, high-return investments to accommodate the limited capacity of households to finance such projects. Assuming that households finance 10 percent of the cost and grant financing is available for 30 percent of the cost, the remaining 60 percent, or US$18 million per year, would probably need to be debt financed by donors and/or IFIs.

Challenges and Opportunities

The portfolio to eliminate energy shortages presents numerous challenges and some opportunities.

The most significant risk is costs. Total investment costs of almost US$3.4 billion by 2020 will need to be carefully reviewed and prioritized, coordinated with

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a tariff policy to share the burden with consumers, and linked with efforts to establish the conditions for private sector participation to complement national resources and development assistance. Net foreign exchange earnings from power exports, estimated at about US$650 million over the 2013–20 period, could play an important role in underwriting new investments.

Second, removing political barriers to the revitalization of electricity trade among Turkmenistan, Uzbekistan, and Tajikistan could enable up to 450 MW of thermal-based winter energy starting as early as 2013. While a move to more open power trading throughout Central Asia would reap benefits for all participants, this will require sustained efforts to develop markets and address political risks. In the interim, efforts should be made to identify and carefully implement selected trades, with strong contract provisions and engagement of third-party mechanisms. Such trades would focus, at least in the short term, on providing greater control and protection to both parties.

Third, coal and natural gas plants will introduce environmental impacts through increases in air pollution, including greenhouse gases (see table 4.6). In addition to the direct ecological and human costs, international concern for climate change and the need to reduce global emissions could constrain access to financing for new coal development and related power generation.

Table 4.6 Emissions from New Thermal Generation (to 2020)

	Emissions		*Monetized emissions*	
CO_2	Million tons	8.7	NPV, US$ millions	191
SO_x	Thousand tons	11	NPV, US$ millions	1
NO_x	Thousand tons	12	NPV, US$ millions	8
Total				**200**

Source: World Bank data.
Note: NPV = net present value.

Notes

1. "Least cost" is defined within the set of alternatives for this study, namely all alternatives excluding hydropower-storage projects.
2. Hydropower share of total installed capacity will remain higher, at 75 percent, accounting for the additional capacity available in summer. However, as noted previously, this capacity is not available in winter due to low flows.
3. The impact of reducing power demand through tariff increases is not included in this economic cost because no investments are required for this measure (apart from the cost of providing social safety nets for low-income households).
4. The average ("levelized") cost is about 0.43 cents per kW hour for T&D loss reduction and about 1.7 cents per kW hour for end-use efficiency measures. If the LRAIC were to be computed on the costs of new supply capacity only, excluding these demand-side measures, then the LRAIC would be 16.4 cents per kW hour excluding export revenues and 14.1 per kW hour including export revenues.

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5. This is because future financial subsidies depend on factors that are not presently knowable, including the terms of financing arranged for investments in new power supply capacity and the taxes and duties levied on power supply and consumption.
6. This GDP projection is based on the actual Tajik GDP of US$5.64 billion in 2010 and 5.7 percent growth in 2011. GDP growth was projected at 4.0 percent per year from 2031 to 2040 for the power demand forecast.

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CHAPTER 5

The Long-Term View

The environment for energy development in Tajikistan has changed dramatically since independence, with very strong growth in demand but loss of sources of thermal supplies during winter. Although eliminating the energy deficit is paramount, efforts must also be made to set a solid foundation for the future and prevent a recurrence of the current crisis. Looking beyond 2020, hydropower would remain the backbone of the Tajik energy system, but new approaches to identifying, designing, and operating projects are needed for maximum value. Also, the level of dependence on imported resources embedded in the short-term plan can be moderated by concerted efforts in natural resource development within Tajikistan and creation of new trade routes outside Tajikistan.

This section outlines two areas for attention to set a firm basis for sustainable energy development for Tajikistan: (1) maximizing the value of hydropower, and (2) securing a hydrothermal balance.

Maximizing the Value of Hydropower

Contrary to the near-term focus on thermal resources (new thermal-fired plants and imports), investment needs past 2020 focus on the country's hydropower resource. Based on currently identified projects, run-of-river hydropower accounts for almost all additional supply after 2020. Thermal options are limited due to the fuel availability issues and other renewable energy options identified are modest.

Although it appears technically possible to meet growing demand based on thermal and run-of-river hydropower resources, this study reveals some concerns about the long-term role of hydropower.

First, as discussed earlier, hydropower plant (HPPs) can only contribute about one third of their installed capacity to meet winter energy demands due to the significantly reduced availability of water in the winter period. The result is, of the total 14,000 MW of installed capacity in the hydropower system that could be added by 2040 (based on existing package of identified projects), only 4,600 MW is available as firm capacity—more than 9,000 MW generate only during higher summer and fall flow, but do not actually help meet winter energy

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shortages. As a consequence, the cost per unit of firm capacity of many hydropower plants exceeds thermal equivalents and so significantly adds to the economic burden of meeting demand.

Second, exports pose both an opportunity and risk. The analysis incorporates two significant transmission investments to convert excess summer generation into export earnings from South Asia summer markets: the Central Asia—South Asia (Transmission Line) (CASA-1000) line currently under consideration and a second line of equal size that could be on line in 2023. The addition of these two lines, plus reconnection to Central Asia, would increase exports to almost 7 terwatt hour by 2025 compared to current negligible levels and fully utilize the added transmission lines. The consequent revenues, as shown by the long-run average incremental cost (LRAIC) estimates, are an important source of investment funds. However, beyond 2025, further additions to summer generation could encounter challenges in finding export routes. Consequently, water would have to be spilled, undermining the economic feasibility of the hydropower plants, compromising private investment and posing financial risks to the GoT.

Third, meeting demand after 2020 will require exploiting run-of-river plants on the Pyanj River for 85 percent of new supply. Beyond 2025, the dependence grows. In fact, run-of-river hydropower projects on Tajik rivers supply only 340 MW firm capacity and are not sufficient to meet demand through to 2040. The predominance of the Pyanj is due in part to favorable hydrology, larger power plants, and higher load factors, resulting in lower costs of firm energy than the projects identified for the Tajik rivers. Transborder projects could help both countries but could also be difficult to develop and may result in less firm capacity or longer development times than assumed in this analysis.

Given hydropower's central role in the country's development aspirations and possibilities, streamlining exploitation and aligning with domestic needs and export capacity will help to maximize the value of the resource. The following approaches to hydropower development are suggested:

- **"Rightsizing" hydropower projects:** The high cost of hydropower may well be the result of designing plants on the basis of installed capacity to take advantage of high summer flows. This approach was realistic when summer exports were guaranteed through the now-defunct integrated regional system. However, in today's environment, designing and building for installed capacity means plants are able to generate at only partial capacity during winter shortages, with considerable capacity lying idle when flows are low. Furthermore, as shown by the analysis, generation in excess of domestic demand in summer cannot always be exported, resulting in high costs for every kWh produced in winter.

  A revised approach, shifting the planning criterion to meet domestic demand at least cost, would match investments and project size to winter flows—"rightsizing" projects to demand and water availability. This would reduce capital costs without compromisng generation of needed winter power. It avoids capacity lying idle during winter months and spilling water in summer

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months. The result is lower overall costs and more attractive investments returns. Rightsized projects may also enable faster development and will cost less.

- **Aligning exports with domestic needs:** Rightsizing does not eliminate opportunities for exports. Rather, it realigns power investments with the development of stable export markets. Tajikistan is fortunate to be located near large markets with high summer electricity demand. Given the considerable technical potential for hydropower in Tajikistan and the Pyanj, adequate infrastructure to get the electricity to those customers, and financing opportunities will be the determining development issues.
- **Focused HPP development**: Assessment of the supply options under this study can be considered as a first step toward a more focused development of the most promising HPP options in the country. Information on the approximate costs of firm energy, and also other information like firm capacity, network connection issues, and so on, help GoT and Barki Tajik in selecting HPPs for medium-term power system planning. Three factors suggest that a more comprehensive assessment of hydropower resources may be warranted:
  - First, a reconsideration of the locations on the Pyanj River is advisable in order to reduce dependency on border projects that are comparatively far from the existing transmission network and centers of demand (with attendant cost and supply risks).
  - Second, the current list of run-of-river alternatives on Tajik rivers is limited, inadequate to meet domestic supply, and likely not representative of the potential from the 60,000 MW resource.
  - Third, the addition of thermal resources to the Tajik power system will shift the role of hydropower from base load to higher value-added services, such as providing power during the hours of highest demand in the system. This value-added is possible because it is much less expensive for hydropower plants to follow the changes in demand than thermal plants. In order to exploit this value added, designing hydropower projects with reserves of water (storage) should be investigated, while addressing the concerns of, and relationships with, riparian countries (including international standards for managing transboundary water resources). The ability to follow load and so exploit the value-added of hydropower does not require seasonal or multiyear capture of water; smaller storage can provide at least some value.

Securing a Hydrothermal Balance

Maintaining a balance with thermal resources will be important over the long term. Several actions can be followed to secure access to thermal resources as a complement to hydropower development.

- **Domestic reserves of natural gas:** The analysis includes a significant amount of coal-fired generation. Notwithstanding its advantages of security of supply, coal-fired power plants raise concerns regarding CO_2 emissions and other

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environmental hazards. Natural gas offers a superior fuel for thermal generation, with respect to cost, reliability, and environmental footprint. As noted in chapter 3, gaining access to domestic sources of natural gas could be "gamechanger" for Tajikistan, substituting both coal and imports. Accelerated investigations into potential deposits are warranted to determine the size and commercial viability of potential reserves, building on the speculative but interesting survey results.

- **Diversified imports of natural gas:** At present, Tajikistan's only access to natural gas is through Uzbekistan. However, the quickening pace of integration of Central Asia with South Asia opens alternative possibilities. One such possibility—to build a pipeline from Turkmenistan to China via Afghanistan and Tajikistan—was identified by the State-run China National Petroleum Corporation (CNPC) in July, 2012 (*Pahwok Afghan News*, June 6, 2012)as part increasing China's imports from Central Asia (*Turkish Weekly*, August 9, 2012). Bypassing current transit countries of Uzbekistan and Kazakhstan, a pipeline through Tajikistan could be seen as a diversification of transportation routes for China. Such a pipeline would provide access to much needed natural gas for Tajikistan and provide a source of foreign exchange as a transit country. Although formal discussions between Tajikistan and China have not been made public, CNPC has signed a cooperative framework agreement with Turkmenenergo to more than double imports from Turkmenistan beyond the current capacity of 30 bcm (*The Diplomat*, August 6, 2012). The proposal has also been discussed between CNCP and President Karzai of Afghanistan. Access to natural gas imports from Turkmenistan could provide a relatively inexpensive source of firm energy, at about 9 cents per kWh compared to the fourth coal plant at 11 cents per kWh. As Central Asia further integrates with South Asia, and the markets of China stimulate energy development, alternative opportunities for both Tajik imports of power and natural gas could be pursued. Central Asia Power System (CAPS) provides excellent opportunities for benefits among the four Central Asia country members. In addition, expanded linkages to the Russian Federation, in the north, China in the south and east, and the Islamic Republic of Iran in the west would diversify trade, mitigate risk, and expand opportunities to share hydropower benefits to a wider mixed energy system. This is a long-term vision, necessitating considerable development of energy markets and interconnections, but is increasingly possible with shared development with the Kyrgyz Republic, increasingly sophisticated energy management and investment by Kazakhstan, greater economic integration with Afghanistan and Turkmenistan, and Chinese interest in new gas pipeline routes from Central Asia.

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CHAPTER 6

Priority Actions

Tajikistan faces a crisis in energy security with serious economic and social consequences. Limited readily available domestic resources, breakdown in energy trade within Central Asia, an aged energy infrastructure, and a mismatch between economic costs and prices have hindered Tajikistan's ability to provide electricity to its citizens throughout the year. In 2012, winter electricity shortages were estimated at 2,700 GWh. In the absence of any offsetting measures, these deficits could increase to over 6,800 GWh and 2,550 MW by 2020. Without immediate attention, the electricity crisis in Tajikistan could affect stability in the country and the region.

There is no single solution to the crisis. Closing the gap between demand and supply will require a package of initiatives that (1) controls demand; (2) adds new supply; (3) revitalizes imports; and (4) manages the cost of these initiatives. Given the conditions facing Tajikistan, these shortages will not be eliminated immediately but could, with concerted effort, be managed by 2016. The GoT also needs to consider a new basis for long-term security of supply through changes in energy policy and development of the hydropower resource. Energy planning and expansion must focus on short-term deficits in domestic supply with projects appropriately designed for winter hydrological conditions, while export development should be focused on strengthening the possibility for evacuating supply though new transmission lines, such as Central Asia—South Asia (Transmission Line) (CASA-1000).

Table 6.1 consolidates actions to eliminate the deficit and prepare for the longer term into four key categories:

- **Energy efficiency** to prepare a comprehensive plan to reduce the burden on the electrical system and engage Tajik Aluminum Company (TALCO) in energy management and conservation
- **Investment preparation** for new supply, rehabilitation, trade infrastructure, and, to a lesser extent, EEPs; this category also includes preparation of a financing plan in light of the US$3.4 billion expected expenditures to 2020

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Table 6.1 Power Supply Alternatives for Tajikistan—Priority Actions to 2020

	Action	*Winter Energy (GWh)*	*Investment (US$ millions)*	*c/kWh*
Energy efficiency	Encourage conservation through pricing (tariff)	1,339	—	—
	Accelerate T&D energy loss reduction programs	771	36	<1
	Strengthen demand-side energy efficiency measures (incl. TALCO)	634	144	<1, as a group
	Switch heating demand away from electricity	357	100	5
	TALCO winter maintenance program	150	—	—
	Subtotal	**3,250**	**280**	
Investment preparation	Prepare financing plan	n.a.	—	—
	Rehabilitation – Protect existing hydropower with priority on Nurek	n.a.	1,105	n.a.
	Dushanbe –2 (dual fired)	1,000	349	8.7
	Shurob-1/2 (dual fired)	2,208	1,046	9.9
	Sanobad (run-of-river hydropower)	539	285	3.5
	Subtotal	**3,747**	**2,785**	
Trade promotion	Reconnect with Central Asia Power System	800	Negligible	6.0
	Develop Turkmenistan/Afghanistan power links	1,710	Included in tariff	11.8
	Construct transmission lines for exports		360	n.a.
	Diversify trade routes south and north		No estimate	No estimate
	Subtotal	**2,510**	**360**	
Energy policy	Develop exports in line with domestic needs		n.a.	n.a.
	Reassess hydropower (rightsizing, new sites, storage)		Potential cost savings	
	Accelerate natural gas investigations		n.a.	n.a.
	Revise tariff policy (incl. social safety nets)		n.a.	n.a.
	Subtotal	**n.a.**	**n.a.**	**n.a.**

Source: World Bank data.
Notes: GWh = gigawatt hour; kWh = kilowatt hour; n.a. = not applicable; — = not available; TALCO = Tajik aluminum company.

- **Trade relations** to begin a revitalization of trade with the Central Asia Power System and to develop nontraditional routes for electricity trade and natural gas imports
- **Energy policies** to balance energy development for domestic and export objectives, revise tariff policies including provisions for the poor and vulnerable, and strengthen analysis and resource assessment to adapt hydropower design to the new economic conditions and accelerate prospecting for a domestic source of natural gas, both of which will fundamentally shape Tajikistan's future energy security.

Tajikistan's Winter Energy Crisis: Electricity Supply and Demand Alternatives
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APPENDIX A

Methodology

General Approach

The identification of power supply alternatives comprise three main steps:

- In a first step, a projection is made of the future power demand in Tajikistan. This projection considers economic growth and economic efficiency through tariff management and possible energy efficiency measures. It includes an estimate of demand that is currently not met due to supply shortages.
- The second step is the assessment of individual power supply options. Under this activity, a range of possible individual power supply options is identified and described.
- These two inputs form the basis for the portfolio assessment in which power supply and energy efficiency alternatives are combined into portfolios to meet demand and export opportunities. Portfolios are compared under key objectives and criteria.

Methodology of Demand Forecast

The demand forecast forms the basis for the portfolio analysis and has a significant impact on its outcome. An overly optimistic demand forecast can lead to unnecessarily high investments in generation capacity and underutilization of plants, diverting resources from better uses. Too low a demand forecast can lead to insufficient investments, resulting in continued energy deficits. The projections of demand for electricity in Tajikistan cover the period 2012–40. The demand is projected in terms of electrical energy (GWh) separately for energy demand in summer (April to September) and in winter (October to March) and in terms of peak load (MW). The demand is further broken down by customer category and sector: Industry, Pumping/Irrigation, Agriculture excluding pumping, Government, Residential, Others, and the aluminum factory Tajik Aluminum Company (TALCO). The demand forecast is based on a World Bank-contracted analysis by SNC Lavalin, specifically for this study.

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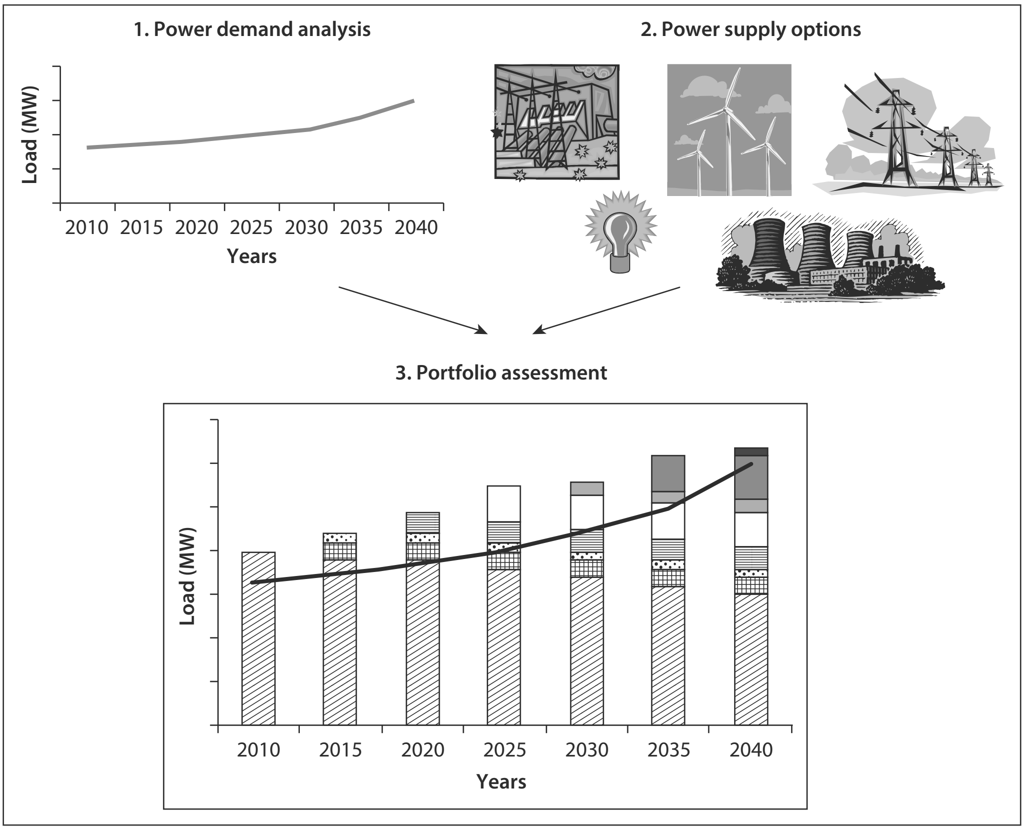
Figure A.1 Main Components of Portfolio Analysis



Source: World Bank.

Tajikistan's current winter energy shortages have two significant implications for the demand analysis and alternatives assessment. First, forecasting from current consumption levels will underestimate the need for power unless unmet demand is included. Unmet demand (also referred to as unserved demand) is estimated based on degree days and current generation (SNC Lavalin 2011).

Second, shortages occur only in winter when temperatures are lowest and generation from hydropower plants is curtailed due to hydrologic conditions. In planning additional supply, focus is on the winter period and times of highest (peak) demand. Peak demand is used to plan investments so that power would be available as needed throughout the day, and translated into energy supply to assess impact on the winter deficit.

Demand is also affected by demand control measures—actions to reduce the overall burden on the power system. Energy efficiency measures (including switching customers away from electricity) will reduce both average and peak demand.

The focus of this study is the main electric system. The integrated grid system in Tajikistan serves approximately 99 percent of the population. Supplying the remaining 1percent includes future connection to the main system or local small sources of power. This component of demand is not included in the study.

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Forecasting demand is an imperfect science, affected by numerous uncertainties (such as economic growth and industrial expansion) and quality of data on current demand. At present, gaps in data limit the rigor associated with a traditional demand forecasting exercise. The current load forecasting approach is satisfactory for the purpose of long-term forecasting, but would need to be upgraded for specific feasibility studies.

Identification of Supply Alternatives

Demand (after energy efficiency measures) can be met by a range of electricity sources that can supply capacity and/or energy. Supply options include hydropower plants (both storage and run-of-river plants), thermal power plants, renewable energy resources, and power imports. Rehabilitation of existing sources of power is likewise considered as supply options; rehabilitation encompasses restoring generating capability and technological upgrades to increase capacity.

The initial list of supply options was taken from the stocktaking exercise initiated by the World Bank as preparatory work for this study and updated by the consultant. The preparatory work involved the collection of existing studies, project proposals, system expansion plans and system assessments from the Government of Tajikistan (GoT), Barki Tajik, development partners and nongovernmental organization (NGOs).

In addition, other options were assessed that have not so far been considered by GoT/Barki Tajik, but which, in the opinion of the consultant, could be potential sources of power in the future. In this regard, Fichtner assessed renewable energy sources, gas-fired power plants, emergency diesel power plants, and alternative import options.

In a prescreening process, options were excluded for which realization within the next 10–20 years is unrealistic for technical reasons, including hydropower options with reservoir capacity to store water over a growing season and that could affect—or be perceived to affect—flows into neighboring countries. This revision resulted in the exclusion of four projects from the list of eligible options, including two of the larger storage plants: Rogun on the Vakhsh River in Tajikistan and Dashtijum on the Pyanj River on the border with Afghanistan.[1]

Information was collected on each supply alternative according to a range of planning criteria to generate a database of economic, social, environmental, and technical characteristics of each alternative.

Development and Assessment of Portfolios

A portfolio is a combination of supply and energy efficiency alternatives that meets electricity demand. Initially, the demand/supply balance was examined to the year 2040, but later focused to 2020, given (1) the urgency of current winter energy crisis; and (2) uncertainty in project data beyond 2020. Specifically, portfolios are developed to address winter energy shortages by selecting alternatives

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Table A.1 Criteria Selected to Describe Power Supply Alternatives

Category	*Objective*	*Criterion*	*#*	*Indicator*	*Unit*
Economic viability	Lowest cost	Cost	1	Net present value of cost over the planning horizon, including cost of unserved energy	US$ millions
			2	Net of foreign exchange revenues	
	Shortest time to eliminate winter shortages	Time until elimination of winter shortage	3	Years with unserved energy	Number of years
Socio-economic impacts	Lowest negative impacts	Involuntary resettlement	4	Number of people to be resettled over the planning horizon (undiscounted)	# of people
	Highest positive impacts	Employment	5	NPV of direct employment created over the planning horizon	person years
Environmental impacts	Lowest negative impacts/ highest positive impacts	Land requirements	6	Area of reservoir	hectares
			7	Area for waste disposal	hectares
		Hydrological impacts	8	SEA criteria aggregated	Scale 1–5
		Terrestrial ecosystems	9	Impact on a nationally or internationally protected area/national park/Ramsar site	Scale 1–5
		Species at risk	10	Potential occurrence of rare or endangered species in the project area	Scale 1–5
		Emissions	11	NPV of greenhouse gas emissions over the planning horizon	tons CO_2/kWh
			12	NPV of air pollutant emissions over the planning horizon	tons NOx/kWh, tons SOx/kWh, tons particulates/kWh
Water management	Lowest transboundary impacts	Transboundary effect	13	Downstream impacts at relevant rivers	% change in flow at border during vegetation period
	Opportunity of multi-purpose use	Additional use of water for nonpower purposes	14	Additional use of water for: water supply/irrigation/flood and drought management	# of multipurpose plants
Supply security	Minimal import dependency	Import dependency	15	Imported capacity as % of peak demand (average and maximum during planning horizon)	Import capacity as % of peak load
	Reliability of power system	Appropriate reserve margin	16	Reserve margin: margin of installed capacity over peak load and margin of firm capacity over peak load (average and minimum during planning horizon)	% of peak load

Source: World Bank data.
Note: SEA = Strategic Environment Assessment.

to supply firm capacity (rather than installed capacity). Portfolios can be assembled based on different objectives and compared/assessed according to a range of development criteria. This study examines the portfolio that meets winter peak demand at least cost. Least cost is the combination of alternatives that minimizes investment and operating costs while accounting for possible export revenues.[2]

In addition, a second portfolio explored the combination of supply and demand options to eliminate the deficit as rapidly as possible. However, differences with the main portfolio were not significant and included very high-cost options. Instead, additional measures were identified that could accelerate deficit reduction subject to more rigorous analysis. These included increasing the planned capacity of Dushanbe-2 thermal plant, additional load winter management at TALCO, more ambitious EEP, and expanded imports.

The portfolio reflects least cost among the eligible alternatives. However, the analysis also describes each portfolio in terms of environmental, social, and development criteria. The specific set of criteria was developed based on energy planning practice and consultation with the GoT, BT, NGOs, and the World Bank. These criteria are detailed in five categories in the following table. The results are presented individually for each criterion; they are neither weighted nor aggregated.

The full database for each alternative (see appendix E) also includes technical project descriptors such as design discharge, installed and firm capacity, and average annual generation.

Notes

1. Rogun HPP, the most significant storage HPP is currently the subject of techno-economic and environmental/social assessment studies. These studies will update 2009 data and ensure incremental design and standards. Data for this plant are not currently available. Dashtijum is a 4,000 MW prospect on the Pyanj River, an undeveloped river shared with Afghanistan; no planning data are available. Both rivers are tributaries to the Amu Darya River (Vakhsh accounts for 30 percent of flows while the Pyanj accounts for the remaining 70 percent).
2. Note that least cost is defined within the set of alternatives for this study, namely all options excluding hydropower storage projects. The portfolios considered may or may not be least cost overall. Because storage projects supply firm capacity, data from both Rogun and Dashtijum are required to confirm the least cost portfolio for Tajikistan.

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APPENDIX B

Electricity Trade in Central Asia

Background

Electricity trade is clearly one of the crucial options which Tajikistan (given its geographic location) simply cannot afford to ignore in its efforts to overcome the inherently skewed nature of its supply system with summer surpluses and winter deficits. The mismatch between the supply capability, which declines substantially in winter in a predominantly hydro system, and demand, which increases sharply during winter due to the heating needs, is the primary cause of such seasonal surpluses and deficits. By adding new capacity at significant costs, the winter deficits could be moderated in the medium to long term but the summer surpluses will also increase and unless they could be exported would reduce the attractiveness of such investments. Thus exporting summer surpluses and meeting winter deficits through imports is a financially sound option for Tajikistan.

Tajikistan followed such an approach as a member of the Central Asian Power System (CAPS), which consisted of South Kazakhstan, the Kyrgyz Republic, Tajikistan, Uzbekistan, and Turkmenistan and operated as a synchronized regional grid (map B.1 next page).

The Tajik system earlier consisted of two separate parts: the northern part with a large demand was connected to northern Uzbekistan and the Kyrgyz Republic and the southern part with most of the generation was connected to southern Uzbekistan. Since the two parts were not interconnected, Tajikistan sent much of its generated energy to southern Uzbekistan and received from the northern part of Uzbekistan equivalent or needed energy on a barter basis. This suited Uzbekistan well since most of its generation was in the northeast and much of the demand was in the south. Also during 2007–09, Tajikistan received 1.2 terawatt hour of electricity in winters from Turkmenistan via Uzbekistan. Turkmenistan islanded one of its generation units and supplied power through the Uzbekistan system. This provided some relief to Tajikistan until early 2009. Uzbekistan interrupted Turkmen electricity deliveries to Tajikistan on January 1, 2009, because of technical problems in Uzbekistan's Karakul substation.

During 2008/09 there were two major developments. First, Tajikistan had constructed a North-South 500 kilovolts line connecting its previously separated

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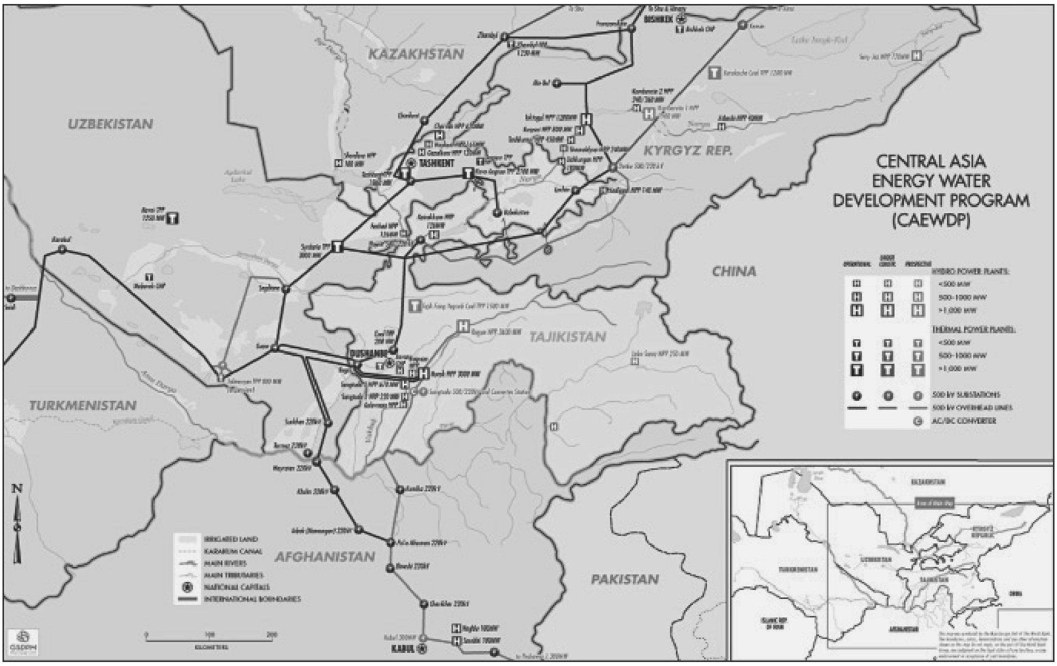
Map B.1 Map of the Central Asia Power System



Source: World Bank.

northern and southern parts. This made the large power flows through Uzbekistan unnecessary. Second, in the context of an unusually cold winter it was reported that Tajikistan, the Kyrgyz Republic, and Uzbekistan drew excessive power from the regional grid far beyond what they were entitled to draw, jeopardizing the stability of the North-South 500 kilovolts Kazakh link and creating serious supply shortages in South Kazakhstan.[1] Kazakhstan immediately withdrew from CAPS, followed by Uzbekistan, which also withdrew from CAPS. Subsequently Kazakhstan, the Kyrgyz Republic, and Uzbekistan rejoined CAPS, largely because of the intricate water energy linkages in the Syr Darya basin and practically interwoven nature of the Kyrgyz Republic and Uzbekistan systems. But Tajikistan became fully isolated from CAPS and its import from Turkmenistan could no longer take place.

It is unfortunate that by a lack of grid discipline the Tajik system became isolated from CAPS. Tajikistan continued to receive some power supply from Uzbekistan in 2010 and 2011 for its areas in the north that were not connected with the main grid. Tajikistan has since connected these areas to its grid, and it does not import any power from Uzbekistan. The isolation of Tajik grid from CAPS has made the problems of Tajikistan even more acute than before. It is believed to spill water enough to generate 3 terawatt hour of electricity (without generating any power) at Nurek in summer, owing to its inability to export the summer surplus of electricity. Its exports are limited to about 600 GWh per year to Afghanistan during the summer season. The growth of these exports to

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Afghanistan would depend on how fast the distribution and transmission network is developed in North- East part of Afghanistan. It also faces competition from Uzbekistan with its year-around power supply to Afghanistan. Afghanistan is also working with Turkmenistan to increase its power imports for its Northern region. Without any imports the winter shortages in Tajikistan are estimated at around 2.5–2.75 terawatt hour during winter months (corresponding approximately to about 1,200 MW of firm capacity).

In the longer term, additional hydro- or thermal power[2]generating capacities would be built to meet these winter deficits. Until Tajikistan will be able to join the CAPS again, the problem will have to be handled through an array of measures including increased import of gas for space heating, energy use-efficiency improvements, adjustments to the production schedules of the Tajik Aluminum smelter, demand management measures including effective tariff adjustments and electricity imports by special means. It is in this context that electricity trade options are being discussed.

It may be a prudent strategy to move toward integrated and complex trade arrangements through a series of small steps. It would be useful to start with trading electricity on the basis of commercial Power Purchase Agreement (PPAs), where payment is ensured and supply is limited to the quantities covered by the PPA. Subject to reaching such arrangements, certain import options from Uzbekistan and from Turkmenistan (through Uzbekistan or Afghanistan) could be considered.

Given the predominance of thermal power plants and their types, Uzbek system had always faced peak demand problems especially in the winter and had to rely on peak power exchanges with Tajikistan and the Kyrgyz Republic (box B.1). With the Isolation of the Tajik system the problem has become somewhat more acute. Uzbekistan is installing new Combined-Cycle Gas Turbine (CCGT) and some coal-based plants to meet its shortfall. After installation of these plants, Uzbekistan should be able to provide off-peak power exports to Tajikistan during winter and improve utilization of its new plants' capacity.

Box B.1 Uzbekistan's Energy Profile

At the end of 2011Uzbekistan had proven gas reserves of 1,600 bcm and a reserves-production ratio of 28.1 years. It is believed to have a lot more gas yet to be discovered, especially in the Fergana area. In 2011, it produced 57 bcm of gas (1.7 percent of world production), consumed 49.1 bcm (1.5 percent of world consumption), and exported the balance to the Russian Federation, the Kyrgyz Republic, and Tajikistan. It has more than 171 discovered oil and gas fields of which 52 produce gas. Gas flaring of associated gas was estimated at 1.9 bcm in 2010 and programs to reduce it and use the gas are ongoing. A number of Chinese and Russian operators have Power Sale Agreements and investments in the sector. Uzbekistan also concluded an export contract (for 10 bcm per year) to China from 2014 when the capacity of the Turkmenistan-Kazakhstan-Uzbekistan pipeline to China would be expanded. Uzbekistan is

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Box B.1 Uzbekistan's Energy Profile *(continued)*

planning to triple its export volumes by 2020. There are reports of domestic shortages of gas especially during winter, but it is believed that Uzbekistan can overcome these with the proposed set of measures like shifting its gas-based generation to more efficient combined-cycle gas turbines, increasing share of coal-based generation and with appropriate price reform.

In 2011, Uzbekistan had a total installed power generation capacity of about 12,500 MW generating about 51.5 TWh to meet a peak demand of about 8,500 MW. Its peak demand is forecast to grow at 3 percent per year to 15,030 MW by 2030. At the same time the energy sent out is expected to grow at 2.7 percent per year to 88.3 TWh.

Thus if Tajikistan were to offer a good price and tight PPA, Uzbekistan could likely consider supplying about 200 MW to 250 MW for five months. Daily supply schedule has to be agreed upon in the advance along with remedies for variation beyond a specified range. Payment security, through arrangements like an escrow arrangement in a foreign bank designated in hard currency or by an irrevocable and divisible letter of credit arrangement would improve the sustainability of trade transactions. The PPA could also be subject to international arbitration and could be under the provisions of Energy Charter Treaty (ECT), since both countries are members of ECT.

Turkmenistan has ample gas resources to fuel its power plants and has even now some excess generation capacity to supply about 200 MW to 300 MW to Tajikistan. During 2007–09 it was supplying 1.2 terawatt hour each winter to Tajikistan. It can with relative ease add gas turbines (GTs) or CCGTs if there is a firm remunerative contract (box B.2 on Turkmenistan energy profile). Turkmenistan is keen on diversifying markets for its energy exports through gas and electricity deals. (box B.2 on Turkmenistan energy profile).

Box B.2 Energy Profile of Turkmenistan

With a proven natural gas reserve of 24.3 tcm, Turkmenistan has the fourth largest gas reserves in the world after Russia, the Islamic Republic of Iran, and Qatar. Its production in 2011 was 59.5 bcm and its consumption was only 25 bcm. It exported the remaining 34.6 bcm (14.3 bcm to China, 10.2 bcm to the Islamic Republic of Iran and 10.1 bcm to Russia).

At the end of 2011 Turkmenistan had an installed capacity of 4,110 MW, of which about 1,790 MW of capacity consisted of large-sized modern gas turbines. Recent capacity additions included (a) 254 MW GT at Dasoguez (2007), (b) 254 MW GT at Akhal near Ashgabat (February 2010), (c) 254 MW GT at Awaza near Caspian Sea (April, 2010), and (d) 2 x 127.1 MW GT units at Balkanabat. The generation in 2011 was 18.3 TWh. Of this 2.5 TWh was exported to the Islamic Republic of Iran, Afghanistan, Armenia, and Azerbaijan. Export to Afghanistan in 2011 was about 50 MW (354 GWh) through two 110 kV lines with a total capacity of 80 MW.

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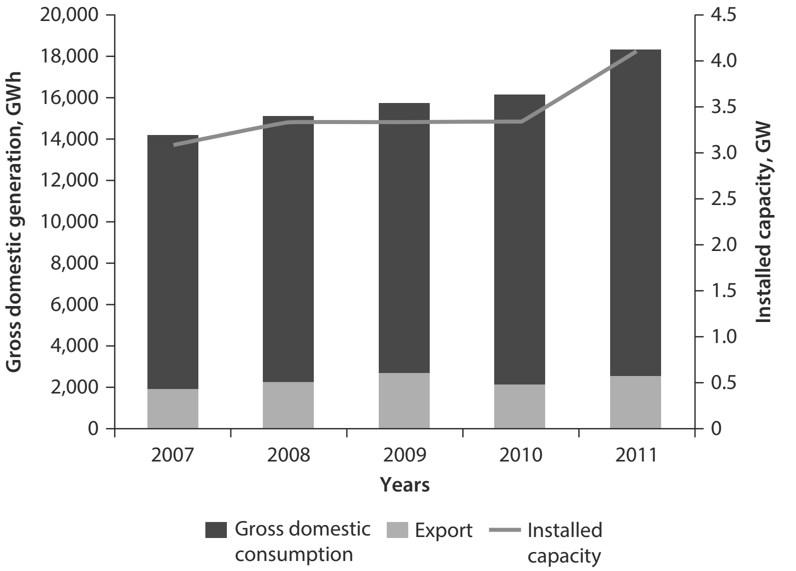
Box B.2 Energy Profile of Turkmenistan *(continued)*

According to the publicly referenced government plans, total generation will increase to 27.4 TWh by 2020 and to 35.5 TWh by 2030. Export is expected to be about 6 TWh by 2020. To enable this four new combined cycle projects with a total capacity of 1,496 MW will be added.

Figure B.2.1 Annual Electricity Generation and Export of Turkmenistan



Turkmenistan is planning to increase its exports to Afghanistan to 1.2 TWh by 2014 by constructing a new generation plant, building a new 500 kV line to the Afghan border and rehabilitating the existing 110 kV lines.

If a PPA-based contract for 500 MW between Turkmenistan and Tajikistan could be arranged, then Turkmenistan could export power to Tajikistan in any of the following three ways:

- As it did in 2007–09, it can provide 500 MW of supply to Karakul substation of the Uzbekistan system in an island mode. This will be absorbed by the southern part of the Uzbekistan system, which, on the basis of a swap arrangement, can supply equivalent power from its northeastern part to the northern part of Tajikistan, again in an island mode. Such islanding operation may be difficult in the southern part of Uzbekistan. Apart from a PPA between Turkmenistan and Tajikistan, this transaction would need a swap agreement with Uzbekistan. A three-cornered agreement could also be an alternative.
- It could build a 500-MW high voltage alternating current/direct current (HV AC/DC) back-to-back convertor on its border and connect to the Uzbek grid

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asynchronously and supply power to Uzbekistan. Uzbekistan may then build a similar 500 kilovolts back-to-back HV AC/DC convertor station at its northeastern border and send power from Tajikistan asynchronously. Thus under this option the links among Turkmenistan, Uzbekistan, and Tajikistan would be asynchronous. This will give control to Turkmenistan and Uzbekistan to allow flows only so long as the quantity and payment conforms to the PPA and swap agreements.

- The third option would be for Turkmenistan to export power to Tajikistan through Afghanistan. In this case the continuation of the 500 kilovolts line from Turkmenistan needs to be built in Afghanistan from Andkhoy right up to Phul-e-Khumri, where it could connect to the planned Central Asia—South Asia (Transmission Line) (CASA-1000) DC line through a HV AC/DC convertor. Then Turkmenistan power could flow to Tajikistan in winter and to Pakistan during the remaining seven months. A variation of this option would be to locate the HV AC/DC convertor closer to Turkmenistan and build the Andkhoy-Phul-e-Khumri line as a DC line.

Given the complexities of developing the Afghan grid, the third option appears somewhat unlikely. Technically back-to-back HV AC/DC asynchronous connections among Turkmenistan, Uzbekistan, and Tajikistan would be a very sound arrangement, removing synchronization problems and the possibility of excessive withdrawal. This could also foster trust among the participating countries. Such back-to-back High-Voltage Direct Current (HVDC) convertor stations were planned for Georgian power exports to Turkey. They have been used in various parts of India to interconnect different regions and state grids. They are modular in design and capacities could be increased in stages at no great cost penalty. The prices of such back-to-back convertors seem to have come down significantly in the last few years. However their role after Tajikistan synchronizes with CAPS through Datka-Khojhand 500 kilovolts line is constructed is not clear. In that event both Uzbekistan and Tajikistan will be members of CAPS and operating at the same frequency, but there will be no direct connections between Tajikistan and Uzbekistan. The time frame for the construction of Datka-Khojhand line is also not clear, though Kyrgyzstan is pressing that it should be constructed as a part of the CASA-1000 project. Intuitively, such HV back-to-back AC/DC convertor stations to link the grids of Turkmenistan and Uzbekistan as well as Uzbekistan and Tajikistan will be for the long-term benefit of the CAPS system, even when CAPS operation is fully restored and modernized.

Structuring the transaction to ensure payment to Turkmenistan and ensuring that Uzbekistan will indeed supply to Tajikistan the power it gets from Turkmenistan is somewhat intricate. There should probably a three-cornered contract, under which (1) Turkmenistan will be able claim payment from the letter of credit (LOC) opened by Tajikistan against meter readings showing delivery of power to Uzbekistan system; and (2) once such a delivery had taken place, then the supply or pay obligation will shift Turkmenistan to Uzbekistan.

http://dx.doi.org/10.1596/978-0-8213-9967-5

Also Tajikistan may have to open a separate LOC in favor of Uzbek Energo for the swap fees, which may be expected to be somewhat lower-than-the-normal wheeling charges, as the transaction relieves congestion in the Uzbek grid. Also it may be prudent to include in the scope of the contract some peak power imports from Turkmenistan for the consumption of Uzbekistan. For this portion alone Uzbekistan may have to open LOC in favor of Turkmenistan (box B.3).

Box B.3 Key Elements of the Power Purchase Agreement

Volume of electricity to be supplied hour by hour on working days and holidays is to be fully covered by quantity schedule. The "day ahead" schedule and actual supply and off-take should conform to the contract schedule. Because of the "take or pay" and "supply or pay" conditions in the PPA, no variations in the actual supply or off-take are to be expected. If parties are willing they could agree to tolerate minor variations (up to one percent) from the contract schedule and incorporate it in the PPA.

The parties have to agree on definitions of "peak" and "off-peak" hours and price payable per kWh for supply during such hours for delivery at the designated substation of Tajikistan in the case of a bilateral contract with Uzbekistan and for delivery to the Uzbekistan grid in the case of contract among Tajikistan, Turkmenistan, and Uzbekistan. Similarly the swap fees payable by Tajikistan to Uzbekistan has also to be agreed upon.

The buyer (Tajikistan) will have to open an irrevocable, but divisible LOC in favor of the seller (Turkmenistan or Uzbekistan) covering the entire five months supply for each winter season in US$ in a New York Bank (alternative currencies and Bank locations in an Organisation for Economic Co-operation and Development (OECD) country could also be considered). The seller will be able to draw down from the LOC upon designated delivery, based on meter reading protocol as well as prices incorporated in the PPA. Similar arrangements will apply for the swap fees or wheeling charges.

Perhaps a concessional loan or a grant from an International Financial Institution (IFI) or a bilateral donor could help Tajikistan open the LOC for the first year. The sale proceeds from the consumers could be used for the subsequent years. The presence of the IFI in some form in the transaction could be very helpful for the adherence of all parties to the contract. The possibility of a IFI guarantee of payment could be explored.

Payment risk is covered by "take or pay" provisions supported by LOC arrangements. Supply risk is covered by "supply or pay" conditions. Supply or pay obligation will pass on to Uzbekistan, the moment Turkmenistan delivers power to Uzbekistan in respect of the quantity so delivered.

The transaction needs to be under a law other than local law, preferably under the English law and should be subject to international arbitration. The panel could consist of a nominee each from buyer and seller and a nominee by the relevant IFI—or the arbitration could follow the Energy Charter Treaty of which all the three countries are members.

Tajikistan's Winter Energy Crisis: Electricity Supply and Demand Alternatives
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This appendix suggests interim solutions to partially address Tajikistan's electricity crisis in the short term. The only sustainable long-term solution is to operate the CAPS with Tajikistan rejoining and evolving a workable synchronized operation in which power flows are based on tight PPAs and payment terms. These enforceable PPAs would include clearing arrangements and agreement in terms of specific price for the flows, caused by the real-time need to balance the system. An authority that could enforce grid code adherence and discipline should be pursued by internationalizing the legal structure, staffing, and management of the Unified Dispatch Center (UDC). A modern grid code will be needed and the UDC will need the technical equipment and authority to remotely disconnect systems or reduce power flows if one party violates the grid code (similar to smart grid capability).

It is important to remember that in UCTC (now European Network of Transmission System Operators for Electricity [ENTSO-E]) the basic rule is that each member should have the generation capacity to meet its demand and that this capacity should be substantially that of the member country and partly by firm PPAs with other countries. In other words, no country can be a member without enough capacity of its own and without firm PPAs in place to meet fully its forecast demand (except for only the minimal flows caused by the real time balancing needs). Grid discipline dictates that once demand exceeds the available and contracted capacity the excess load must be shed to avoid illegal withdrawals and system disturbances. The back-to-back HV AC/DC convertor-based import solutions being recommended in this study could become part of the operating procedure of the reformed CAPS.

Notes

1. Such withdrawals by Tajikistan were reported to be greater than 100 GWh.
2. Tajikistan has notable reserves of coal which could be developed. Also in July 2012 the Canadian firm Tethys announced a major discovery of oil (8.5 billion barrels) and gas 114 TCF or 3.23 TCM) in the Fergana valley of Tajikistan.

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APPENDIX C

Willingness to Pay

Willingness to pay (WTP) is an economic concept used to express the valuation placed by a consumer on a good or service such as electricity in terms of money.

WTP is constrained by the consumer's ability to pay, so that it is a function of the consumer's income as well as this quantity of electricity that the individual is purchasing. In other words, the WTP for a given amount of electricity is higher for consumers with higher incomes than for consumers with lower incomes. Hence, measuring WTP for electricity requires a reliable estimate of the consumer's demand for electricity, which is represented as a demand function showing how the quantity of electricity demanded by the consumer varies with the price of electricity faced by the consumer. At one end of this function, a consumer is expected to be willing to pay a high price for consuming a little amount of electricity because the consumer will apply this quantity to the uses that have highest value to the consumer. Under this demand function (according to the principle of declining marginal utility in the language of economists), the consumer's WTP for an additional unit of electricity declines as the amount of electricity consumed increases. The total amount of electricity that the consumer demands is set by the point at which the demand function reaches the actual price paid for electricity, which is the point on the demand function at which the WTP drops to the level of the electricity price.

This demand function can be used to measure the economic benefit of a given amount of electricity consumption in terms of the area under the demand function for this amount. The analysis for this report works with a power demand function that aggregates the demand of all power consumers into a demand function at the level of the power system. The analysis represents this demand in the form of the following semilog relationship between electricity price and the quantity demanded:

$$Q_n = a_n + b_n * \log P_n$$

where P_n is the average marginal tariff in constant price terms faced by electricity consumers in year n of the planning period; Q_n is the system electricity demand

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in year *n* at price P_n; and a_n and b_n are constants. The area under this function for a quantity of electricity between two values for Q_n is solved by using an assumption about the value of the price elasticity of demand for electricity. The average WTP for this amount of electricity is computed from the value for this area divided by this amount of electricity.

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APPENDIX D

Fuel Switching and Energy Efficiency

Electricity savings from fuel switching and demand-side energy efficiency measures are estimated using the following general assumptions:

Table D.1 Energy Efficiency Penetration Assumptions and Summary of Electricity Savings

	2013	*2014*	*2015*	*2016*	*2017*	*2018*	*2019*	*2020*	*2021*	*2022*
Energy efficiency penetration assumptions (%)										
Fuel switching	10	20	30	40	50	60	70	85	100	100
Energy efficiency improvements at TALCO	—	—	68	79	89	100	100	100	100	100
TALCO winter maintenance	—	100	100	100	100	100	100	100	100	100
Building insulation	0	3	10	17	25	40	55	70	85	100
Energy efficiency standards, labeling, and solar water heaters	0	5	10	15	30	45	60	75	90	100
Estimated winter electricity savings from energy efficiency ($)										
Fuel switching	44	88	130	172	214	255	296	357	419	419
Energy efficiency improvements at TALCO	0	0	359	418	475	531	531	531	531	531
TALCO winter maintenance	—	150	150	150	150	150	150	150	150	150
Building insulation	—	1	4	6	9	14	20	25	30	35
Energy efficiency standards, labeling, and solar water heaters	—	5	11	16	32	47	62	78	93	103

Source: World Bank data.
Notes: — = not available; TALCO = Tajik aluminum company.

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Calculation of energy efficiency savings from each of the measures above is presented in the tables below:

Table D.2 Calculation of Electricity Savings from Fuel Switching and Building Insulation

Number of total households	1,100,000
Number of urban households	330,000
Share of electricity-based heating in urban households in 2012	85%
Share of electricity-based heating in urban households by 2022	35%
Estimated average annual electricity demand per household	3,191 kWh/year
Estimated average annual electricity demand per household for heating	2,234 kWh/year
% of existing residential buildings retrofitted by 2022	30%
Estimated reduction in heating demand	30%
Correction factor to adjust for share of households with electricity-based heating	35%
Estimated winter electricity savings from fuel switching	419 GWh
Estimated winter electricity savings from building insulation	35 GWh

Source: World Bank data.
Notes: GWh = gigawatt hour; kWh = kilowatt hour.

Table D.3 Calculation of Electricity Savings from Introduction of Energy Efficiency Standards and Labeling

Penetration rate of refrigerators in 2012	33
Penetration rate of refrigerators in 2022	75
Estimated average annual electricity consumption of a refrigerator in 2012	720 kWh/year
Estimated efficiency gains until 2022	50%
Estimated average annual electricity consumption of a refrigerator in 2022	360 kWh/year
Estimated efficiency gains w/o labeling policy until 2022	25%
Estimated winter electricity savings w/EE standards and labeling policy	83 GWh

Source: World Bank data.
Notes: EE = energy efficiency; GWh = gigawatt hour; kWh = kilowatt hour.

Table D.4 Calculation of Electricity Savings from Increased Use of Solar Water Heaters

Share of households with electric water heaters	30%
Capacity of an average electric water heater	2.5 kW
Replacement/addition of solar water heaters	20%
Annual average operating hours of water heaters	500 hours
Number of households with additional solar water heaters	66,000
Water heating demand covered by solar water heaters	60%
Estimated winter electricity savings from solar water heaters	20 GWh

Source: World Bank data.
Notes: GWh = gigawatt hour; kWh = kilowatt hour.

The following table provides an overview of the energy efficiency measures, identified under the TALCO Energy Audit, most of which can be implemented in one to four years, depending on the technical complexity of measures as well as the maintenance schedule of aluminum cells at TALCO. Those measures marked with (*) would require no additional studies or engineering work before implementation.

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Table D.5 Description of Potential Short- and Medium-Term Energy Efficiency Measures at TALCO

Area	*GROUP 1* *Energy Efficiency Measures with Payback Period <1 year*	*GROUP 2* *Energy Efficiency Measures with Payback Period of 1–3 years*	*GROUP 3* *Energy Efficiency Measures with Payback Period of 3–6 years*
Electrolysis process	– Cleaning of contact anode beam-stem* – Improved welding between anode stem and yoke – Increased yoke/stub dimensions – Replacement and repair of damaged anode stems* – Increasing bus bar dimensions* – Application of anode beam levelling busbar – Preheating of cathodes carbon bocks before casting the iron* – Measurements of electrical resistance cathode carbon-collector bar* – Improved geometry of the stub hole - reduced contact resistance* – Improved connections between riser and anode beam – Increased dimensions of the current riser – Use of long cathode carbon – Improving connections between cathode collector bars and bus bars – Eliminating long current paths	– Install alumina point feeder, change in electrolyte, slotted anodes – Changeover to truck-mounted supply of alumina to the pot-room silos	
Anode production	– Improve backing facilities I – Increase the insulation thickness on the pitch tanks* – Transport coke only in covered wagons – Relining of internal refractory for the calcinations kilns	– Improve baking facilities II – Install two supplementary heat recovery units for hot oil production – Installation of temperature sensors at cast iron foundries*	– Improve baking facilities III
Plant service	– Heat insulation of pipes and valves* – Introduction of energy management system	– Upgrading of outdoor lighting* – Improve the efficiency of autonomous boiler house with boiler E-1/9	– Upgrade of internal lighting* – Reconstruction of the central boiler house – Frequency converters for 250 kW pumps at closed water systems

Source: World Bank data.
Note: kW = kilowatt.

The table below presents the calculation of costs of fuel switching, energy efficiency measures at TALCO, building insulation, introduction of energy efficiency standards/labeling, and solar water heaters.

Table D.6 Costing of Energy Efficiency Measures

	Unit	*Fuel Switching*	*Solar Heater*	*Standard and Labeling Policy*	*Building Insulation (Basic Measures)*	*TALCO Short-Term Measures*	*TALCO Medium-Term Measures*
Installed capacity	MW	193	n.a.	n.a.	n.a.	n.a.	n.a.
Grid losses, electricity		12%	12%	12%	12%	2.5%	2.5%
Reduced consumption of electricity	GWh/yr	419	56	166	35	802	381
Efficiency		85%	n.a.	n.a.	n.a.	n.a.	n.a.
Fuel demand	GWh/yr	440	n.a.	n.a.	n.a.	n.a.	n.a.
Investment cost	$/kW	500	—	—	—	—	—
Total investment	Million $	97	53	5	23	7	80
Interest rate		10%	10%	10%	10%	10%	10%
Depreciation time	Yr	25	10	25	40	20	20
Investment cost	**Million $/yr**	**9.66**	**7.81**	**0.50**	**2.15**	**0.75**	**8.54**
Caloric value	MWh/t	6.20	n.a.	n.a.	n.a.	n.a.	n.a.
Fuel price	$/t	100	n.a.	n.a.	1,022	n.a.	n.a.
Fuel cost	**Million $/yr**	**7.10**	—	—	—	—	—
Specific O&M cost, fixed	% of inv. cost	3%	—	—	—	—	—
Specific O&M cost, fixed	$/kW	15.00	—	—	—	—	—
O&M cost, fixed	Million $/yr	2.90	—	2.00	—	—	—
O&M cost, variable	% of Fuel cost	5%	—	—	—	—	—
O&M cost, variable	Million $/yr	0.35	—	—	—	—	—
O&M cost	**Million $/yr**	**3.25**	—	**2.00**	—	—	—
Fixed cost	Million $/yr	12.56	7.81	2.50	2.15	0.75	8.54
Variable cost	Million $/yr	7.45	—	—	—	—	—
Overall cost	Million $/yr	20.01	7.81	2.50	2.15	0.75	8.54
Unit cost of electricity saved	**Cents/kWh**	**4.8**	**14**	**1.5**	**6.1**	**0.09**	**2.2**

Source: World Bank data.
Notes: GWh = gigawatt hour; kW = kilowatt; kWh = kilowatt hour; MW = megawatt; n.a. = not applicable; — = not available; TALCO = Tajik aluminum company.

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APPENDIX E

Rehabilitation of Existing Hydropower Plants

The table below presents the priority hydropower rehabilitation projects identified by the government for the period 2012–25. The list is based on the information obtained from the government.

Table E.1 Priority Hydropower Plant Rehabilitation Projects

Plant Name	*Year of Comm*	*Inst Cap*	*Avail Cap*	*Incr/ effi gain*	*Cap after Rehab*	*Firm Capacity*		*Winter Energy*		*Invest Cost/ MW*	*Rehab Cost*
						Before Rehab	*After Rehab*	*Before Rehab*	*After Rehab*		
	(*Year*)	(*MW*)	(*MW*)	(*Percent*)	(*MW*)	(*MW*)	(*MW*)	(*GWh*)	(*GWh*)	(*US$/ kW*)	(*US$ Millions*)
Nurek HPP											
Unit 1	1972	333	331	5	350.0	128	134	510	536	300	100
Unit 2	1972	333	331	5	350.0	128	134	510	536	300	100
Unit 3	1973	333	331	5	350.0	128	134	510	536	300	100
Unit 4	1976	333	331	5	350.0	128	134	510	536	300	100
Unit 5	1977	333	331	5	350.0	128	134	510	536	300	100
Unit 6	1977	333	331	5	350.0	128	134	510	536	300	100
Unit 7	1979	333	331	5	350.0	128	134	510	536	300	100
Unit 8	1979	333	331	5	350.0	128	134	510	536	300	100
Unit 9	1979	333	331	5	350.0	128	134	510	536	300	100
Total		**3,000**	**2,979**		**3,150**	**1,152**	**1,210**	**4,592**	**4,822**		**900**

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Table E.1 Priority Hydropower Plant Rehabilitation Projects *(continued)*

						Firm Capacity		*Winter Energy*			
Plant Name	*Year of Comm*	*Inst Cap*	*Avail Cap*	*Incr/ effi gain*	*Cap after Rehab*	*Before Rehab*	*After Rehab*	*Before Rehab*	*After Rehab*	*Invest Cost/ MW*	*Rehab Cost*
	(*Year*)	(*MW*)	(*MW*)	(*Percent*)	(*MW*)	(*MW*)	(*MW*)	(*GWh*)	(*GWh*)	(*US$/ kW*)	(*US$ Millions*)
Kairakkum HPP											
Unit 1	1956	21	21	2.5	21.5	9	9	37	38	500	11
Unit 2	1956	21	21	2.5	21.5	9	9	37	38	500	11
Unit 3	1956	21	21	2.5	21.5	9	9	37	38	500	11
Unit 4	1957	21	21	2.5	21.5	9	9	37	38	500	11
Unit 5	1957	21	21	2.5	21.5	9	9	37	38	500	11
Unit 6	1957	21	21	2.5	21.5	9	9	37	38	500	11
Total		**126**	**126**		**129**	**52**	**53**	**222**	**227**		**63**
Golownaya (Sarband) HPP											
Unit 1	1962	35	34.8	3	35.9	26	27	102	105	500	18
Unit 2	1962	35	34.8	3	35.9	26	27	102	105	500	18
Unit 3	1962	35	34.8	3	35.9	26	27	102	105	500	18
Unit 4	1963	45	44.7	3	46.1	33	34	131	135	500	23
Unit 5	1963	45	44.7	3	46.1	33	34	131	135	500	23
Unit 6	1963	45	44.7	3	46.1	33	34	131	135	500	23
Total		**240**	**238.3**		**246.0**	**178**	**182.7**	**700**	**717.6**		**120**
Perepadnaya HPP											
Unit 1	1958	10.8	8.1	3	11.1	7	7	27	28	500	5
Unit 2	1960	10.8	8.1	3	11.1	7	7	27	28	500	5
Unit 3	1960	8.4	6.3	3	8.6	6	6	21	22	500	4
Total		**30.0**	**22.5**		**30.7**	**20**	**20.4**	**75**	**77.2**		**15**
Centralnaya HPP											
Unit 1	1964	7.6	7.5	3	7.7	4.1	4.2	14	14	500	4
Unit 2	1964	7.6	7.5	3	7.7	4.1	4.2	14	14	500	4
Total		**15.1**	**15.0**		**15.5**	**8.3**	**8.5**	**27**	**27.9**		**8**
Varzob Cascade HPP											
HPP-1/Unit 1	1936	3.7	3.7	34	5.0	0.4	0.6	3	5	500	2
HPP-1/Unit 2	1936	3.7	3.7	34	5.0	0.4	0.6	3	5	500	2
HPP-2/Unit 1	1949	7.2	3.6	**2.5**	7.4	0.7	0.7	5	5	500	4
Total		**14.6**	**11**			**1.5**	**1.9**	**11**	**15**		**8**
Grand total						**1,410**	**1,475**	**5,616**	**5,872**		**1,114**

Source: World Bank data.
Notes: The data for separate units might not add up to the total for the HPP or the cascade of HPPs due to rounding. avail = available; cap = capacity; comm = commissioned; eff = efficiency; GWh = gigawatt hour; HPP = hydropower plant; incr = increase; inst = installed; kW = kilowatt; MW = megawatt.

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APPENDIX F

Description of Supply Alternatives

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Table F.1 Description of Supply Alternatives

		Hydropower													
	Unit	*Shurob HPP*	*Fan-darya*	*Obur-don*	*Sangis-ton*	*Aynin*	*Yavan*	*Dupulin*	*Barshor*	*Anderob*	*Pish*	*Sano-bod*	*Yzgulem*	*Granit Gates*	*Shir-govat*
General information															
River basin/ cascade		Vakhsh	Zara-vshon	Zara-vshon	Zara-vshon	Zara-vshon	Zara-vshon	Zara-vshon	Pyanj	Pyanj	Pyanj	Pyanj	Pyanj	Pyanj	Pyanj
Type		ROR	ROR	STO	ROR	ROR	ROR	ROR	ROR	ROR	ROR	ROR	ROR	ROR	ROR
Design discharge	m^3/s	1,326	125		113	190	25	159				160			
Installed capacity	MW	850	160		140	160	160	90	300	650	320	125	850	2,100	1,900
Firm capacity	MW	99	14		27	30	25	10	28	58	87	125	139	436	300
Average annual generation	GWh p.a	3,043	497		647	729	664	319	763	1,577	1,629	1,088	3,318	9,364	7,272
Firm energy	GWh p.a	865	123		233	259	215	86	244	504	766	1,095	1,214	3,821	2,628
Investment cost	US$ M	1,565	327		292	330	331	190	619	1,291	655	285	1,662	4,020	3,659
Unit cost of average energy	US cents/ kWh	7.2	9.0		6.1	6.2	6.8	8.1	11.3	11.5	5.6	3.5	7.0	7.0	7.5
Criteria															
Unit cost of firm energy	US cents/ kWh	25.5	36.2		17.1	17.3	21.0	30.0	35.5	35.9	12.0	3.5	19.2	17.1	20.7
Earliest date on	Year	2020	2020		2020	2020	2020	2020	2025	2025	2025	2020	2025	2028	2026
Involuntary resettlement	# of people	0	0		0	100	0	0	0	0	0	0	0	0	0
Employment cre-ated	Person-years	16,000	6,500		6,500	6,500	6,500	3,500	16,000	16,000	16,000	6,500	16,000	47,500	26,000
Land requirements (reservoir)	Hectares	150													

table continues next page

Table F.1 Description of Supply Alternatives *(continued)*

		Hydropower													
	Unit	*Shurob HPP*	*Fandarya*	*Obur-don*	*Sangiston*	*Aynin*	*Yavan*	*Dupulin*	*Barshor*	*Anderob*	*Pish*	*Sanobod*	*Yzgulem*	*Granit Gates*	*Shirgovat*
Waste disposal	Hectares														
SEA criteria aggregated	Scale 1–5	2	2		2	2	2	2	2	2	2	2	2	3	3
World heritage site/national park/Ramsar	Scale 1–5	2	2		1	1	1	1	1	1	1	1	1	2	1
Potential occurrence of rare or endangered species in the project area	Scale 1–5	2	2		2	2	2	2	2	2	2	2	2	3	2
Greenhouse emissions	*t* of CO_2/GWh	7.5	0		0	0	0	0	0	0	0	0	0	0	0
Air pollutant emissions	*t* of NOx/GWh	0	0		0	0	0	0	0	0	0	0	0	0	0
Air pollutant emissions	*t* of SOx/GWh	0	0		0	0	0	0	0	0	0	0	0	0	0
Air pollutant emissions	*t* of part./GWh	0	0		0	0	0	0	0	0	0	0	0	0	0
Change in generation of downstream plants	GWh	0	0		0	0	0	0	0	0	0	0	0	0	0
Ability to perform ancillary services	Yes/No	No	No		No	No	No	No	No	No	No	No	No	No	No
Downstream impacts	% of flow	0	0		0	0	0	0	0	0	0	0	0	0	0
Additional use of water for nonpower purposes	Yes/No	Yes	No		No	No	No	Yes	No	No	No	No	No	No	No

table continues next page

Table F.1 Description of Supply Alternatives *(continued)*

		Hydropower											
	Unit	*Hostav*	*Dashti-jum*	*Jumar*	*Moskov*	*Kokcha*	*Sangvor*	*Urfatin*	*Shtien*	*Nurabad-2*	*Nurabad-1*	*Garms*	*SHPP*
General information													
River basin/cascade		Pyanj	Pyanj	Pyanj	Pyanj	Pyanj	Vakhsh	Vakhsh	Vakhsh	Vakhsh	Vakhsh	Vakhsh	
Type		ROR	STO	ROR	ROR	ROR	STO	ROR	ROR	ROR	ROR	ROR	ROR
Design discharge	m^3/s							88	90	138	170	291	
Installed capacity	MW	1,200		2,000	800	350		160	160	120	150	120	35
Firm capacity	MW	456		420	429	82		48	54	38	40	46	7
Average annual generation	GWh p.a	7,122		8,970	5,640	1,664		940	985	723	847	737	175
Firm energy	GWh p.a	3,993		3,682	3,756	721		419	473	336	352	406	61
Investment cost	US$ M	2,309		3,769	1,501	691		349	349	270	310	249	110
Unit cost of average energy	US cents/ kWh	4.8		6.3	3.7	5.8		5.0	4.8	5.1	5.0	4.6	5.0
Criteria													
Unit cost of firm energy	US cents/ kWh	8.6		15.2	5.6	13.4		11.3	10.0	10.9	12.0	8.4	12.0
Earliest date on	Year	2026		2026	2025	2025		2022	2022	2020	2021	2022	2015
Involuntary resettlement	# of people	0		0	0	0		0	0	50	0	0	0
Employment created	Person-years	26,000		26,000	16,000	16,000		6,500	6,500	6,500	6,500	6,500	20,300
Land requirements (reservoir)	Hectares												

table continues next page

Table F.1 Description of Supply Alternatives *(continued)*

		Hydropower											
	Unit	*Hostav*	*Dashti-jum*	*Jumar*	*Moskov*	*Kokcha*	*Sangvor*	*Urfatin*	*Shtien*	*Nurabad-2*	*Nurabad-1*	*Garms*	*SHPP*
Waste disposal	Hectares												
SEA criteria aggregated	Scale 1–5	2		3	2	2		2	2	2	2	2	1
World heritage site/national park/Ramsar	Scale 1–5	1		1	1	1		1	1	1	1	1	1
Potential occurrence of rare or endangered species in the project area	Scale 1–5	2		2	2	1		2	2	2	2	2	1
Greenhouse emissions	*t* of CO2/GWh	0		0	0	0		0	0	0	0	0	0
Air pollutant emissions	*t* of NOx/GWh	0		0	0	0		0	0	0	0	0	0
Air pollutant emissions	*t* of SOx/GWh	0		0	0	0		0	0	0	0	0	0
Air pollutant emissions	*t* of part./GWh	0		0	0	0		0	0	0	0	0	0
Change in generation of downstream plants	GWh	0		0	0	0		0	0	0	0	0	0
Ability to perform ancillary services	Yes/no	No		No	No	No		No	No	No	No	No	No
Downstream impacts	% of flow	0		0	0	0		0	0	0	0	0	0
Additional use of water for nonpower purposes	Yes/no	No		No	No	No		No	No	No	No	No	No

table continues next page

Table F.1 Description of Supply Alternatives *(continued)*

		TPP							RE	Import			
	Unit	*Dushan-be-2*	*Shurob-1 TPP*	*Shurob-2 TPP*	*Fon Yagh-nob I*	*CCGT import gas*	*CCGT domestic gas*	*Emergency Diesel*	*Solar Energy (PV)*	*Import Uzbekistan to Regar*	*Import Uzbekistan to Regar*	*Import Turk-menistan via Afghanistan*	*Import Turk-menistan via Afghanistan*
General information													
Fuel		Coal	Coal	Coal	Coal	Gas	Gas	Diesel	Solar	Import	Import	Import	Import
Type		CHP	TPP	TPP	TPP	TPP	TPP	TPP	RE	IMP	IMP	IMP	IMP
Design discharge	m^3/s												
Installed capacity	MW	200	300	300	500	300	300	100	50	250	250	150	300
Firm capacity	MW	200	300	300	500	300	300	100	0	250	250	150	300
Average annual generation	GWh p.a	736	1,104	1,104	1,840	1,164	1,164	396	77	450	450	570	1,140
Firm energy	GWh p.a	736	1,104	1,104	1,840	1,164	1,164	396	0	450	450	570	1,140
Investment cost	US$ M	349	523	523	1,051	347	347	0	152	0	0	0	0
Unit cost of average energy	US cents/kWh	8.7	9.9	9.9	11.2	9.4	6.8	28.8	25.8	6.0	6.0	11.8	11.8
Criteria													
Unit cost of firm energy	US cents/kWh	8.7	9.9	9.9	11.2	9.4	6.8	28.8	63.6	6.0	6.0	11.8	11.8
Earliest date on	Year	2015	2018	2020	2020	2017	2017	2013	2015	2016	2020	2018	2019
Involuntary resettlement	# of people								0	0	0	0	0
Employment created	Person-years	9,500	14,248	14,248	18,000	4,500	4,500	20	675				
Land requirements (reservoir)	Hectares												
Waste disposal	Hectares	40	60	60	100	0	0	0					
SEA criteria aggregated	Scale 1–5	4	3	3	4	2	2	3	1	1	1	1	1

table continues next page

Table F.1 Description of Supply Alternatives *(continued)*

		TPP							*RE*	*Import*			
	Unit	*Dushan-be-2*	*Shurob-1 TPP*	*Shurob-2 TPP*	*Fon Yagh-nob I*	*CCGT import gas*	*CCGT domestic gas*	*Emergency Diesel*	*Solar Energy (PV)*	*Import Uzbekistan to Regar*	*Import Uzbekistan to Regar*	*Import Turk-menistan via Afghanistan*	*Import Turk-menistan via Afghanistan*
World heritage site /national park / Ramsar	Scale 1–5	1	1	1	1	1	1	1	1	1	1	1	1
Potential occur-rence of rare or endangered species in the project area	Scale 1–5	1	1	1	1	1	1	1	1	1	1	1	1
Greenhouse emissions	*t* of CO2/ GWh	1,016	1,308	1,308	818	367	367	672	0	0	0	0	0
Air pollutant emis-sions	*t* of NOx/ GWh	1.66	1.66	1.66	0.08	1.00	1.00	16.75	0	0	0	0	0
Air pollutant emis-sions	*t* of SOx/ GWh	1.61	1.32	1.32	0.09	0	0	-	0	0	0	0	0
Air pollutant emis-sions	*t* of part./ GWh	0.16	0.16	0.16	0.0016	0	0	0.2	0	0	0	0	0
Change in gen-eration of down-stream plants	GWh												
Ability to perform ancillary services	Yes/no	No	No	No	No	No	No	No	No	Yes	Yes	Yes	Yes
Downstream impacts	% of flow												
Additional use of water for non-power purposes	Yes/no	No	No	No	No	No	No	No	No	No	No	No	No

Source: World Bank data.
Notes: CCGT = combined-cycle gas turbine; CHP = combined heat and power plant; GWh = gigawatt hour; HPP = hydropower plant; IMP = import; kWh = kilowatt hour; MW = megawatt; PV = photovoltaic (solar power); RE = renewable energy; ROR = run-of-river; SEA = Strategic Environment Assessment; SHPP = small hydropower promotion project; STO = Solar Thermal Option; TPP = thermal power plant.

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Tajikistan's Winter Energy Crisis: Electricity Supply and Demand Alternatives
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Tajikistan's Winter Energy Crisis: Electricity Supply and Demand Alternatives is part of the World Bank Studies series. These papers are published to communicate the results of the Bank's ongoing research and to stimulate public discussion.

Tajikistan suffers severe energy shortages in winter, caused by a combination of low hydropower output during winter, when river flows are low, and high demand driven by heating needs. Shortages affect some 70 percent of the population, costing about 3 percent of annual GDP. This figure excludes human and environmental costs, as well as the serious negative effect on the business investment climate.

If no measures are undertaken to address this problem, then current electricity shortages, estimated at about one-quarter of winter demand (2,700 GWh), could increase to more than one-third of winter demand (4,500 GWh) by 2016. The Government of Tajikistan recognizes both the importance and challenges of energy security and has therefore introduced various measures to help meet demand.

Tajikistan's Winter Energy Crisis explores a range of supply and demand alternatives—including thermal, run-of-river hydro, other renewables, energy efficiency, and demand management—to further inform its development partners on the country's efforts to meet its winter energy demand. The study recommends that the Government of Tajikistan

- accelerate its efforts in energy efficiency and demand management, including tariff reform;
- add new dual-fired thermal power supply to complement the existing hydropower supply during winter; and
- pursue energy imports and rebuild regional energy trade routes to leverage surplus electricity supply in neighboring countries.

Energy conservation and demand-side management, effective resource management, and reduction alone could address 40 percent of the shortages, including a significant package of economic measures at the main aluminum smelting plant. The study suggests that by following these recommended actions shortages could be significantly reduced within 4–5 years and a solid base for long-term energy established.

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