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Rethinking energy security and services in practice: National vulnerability and three energy pathways in Tajikistan

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ABSTRACT

To help answer questions about availability, accessibility, sustainability and other *dimensions* of energy security, the *vulnerability* approach concentrates the attention of policymakers on the assessment of risks associated with *natural, technical, political and economic* factors. This understanding, combined with a focus on *energy services* (e.g. lighting, heating, telecommunications, mobility, etc.) helps to prioritize actions to achieve the goal of energy security. This paper conceptualizes energy security as low vulnerability of vital energy systems and sustained provision of modern energy services. Taking Tajikistan as a case, this paper highlights key vulnerabilities including neglect of environmental conditions, insufficient energy production capacity, unreliable and expensive energy imports, dwindling power infrastructure causing technical and economic losses, inadequate transparency in the power sector, lack of regional cooperation in energy and water resources sharing, and inadequate financial resources to address these challenges. Three major proposals presented by the World Bank, the United Nations Development Program, and the Government of Tajikistan to achieve energy security in Tajikistan are evaluated. Specifically, they lack a focus on energy services and therefore overlook people's socio-cultural context and appropriate energy needs. This paper highlights energy services as critical to people's wellbeing and socio-economic development.

1. Introduction

Energy security is a complex and evolving concept (Ang et al., 2015; Brown et al., 2014; Cherp and Jewell, 2014; Hughes, 2009; Löschel et al., 2010; Månsson et al., 2014; Sovacool, 2013; Sovacool and Mukherjee, 2011; Vivoda, 2010; Winzer, 2012). Based on our review of the literature (Laldjebaev et al., 2016), and in agreement with Cherp and Jewell (2014) and Cherp et al. (2012), we adopt the following working definition of energy security: *low vulnerability of vital energy systems and sustained provision of modern energy services.* The *vulnerability* approach offers several advantages over conventional *dimensions* approaches (e.g. "4As" by Kruyt et al., 2009, "4Rs" by Hughes, 2009[1]) to energy security assessment. Firstly, the definition captures the various dimensions (e.g. availability, affordability, sustainability, etc.) of energy security that are outcomes of reduced vulnerability of energy systems arising from four major risk factors: "natural (e.g., resource scarcity, extreme natural events), technical (e.g., aging of infrastructure, technological accidents), political (e.g., intentional restriction of supplies or technologies, sabotage and terrorism), and economic (e.g., high or volatile prices)" (Cherp et al., 2012, p. 330). Secondly, along with exposure to risk, the resilience of energy systems is also considered. Thirdly, flexibility of application in diverse contexts allows for "(a) delineating vital energy systems; (b) exploring their vulnerabilities; and (c) understanding the political process which leads to the prioritization of certain energy systems and vulnerabilities" (Cherp and Jewell, 2014, p. 418). Finally, it grounds the assessment on provision of modern energy services, which is the ultimate rationale for energy security policies.

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[1] We will not discuss these approaches for they have been critiqued in detail by Cherp and Jewell (2014).

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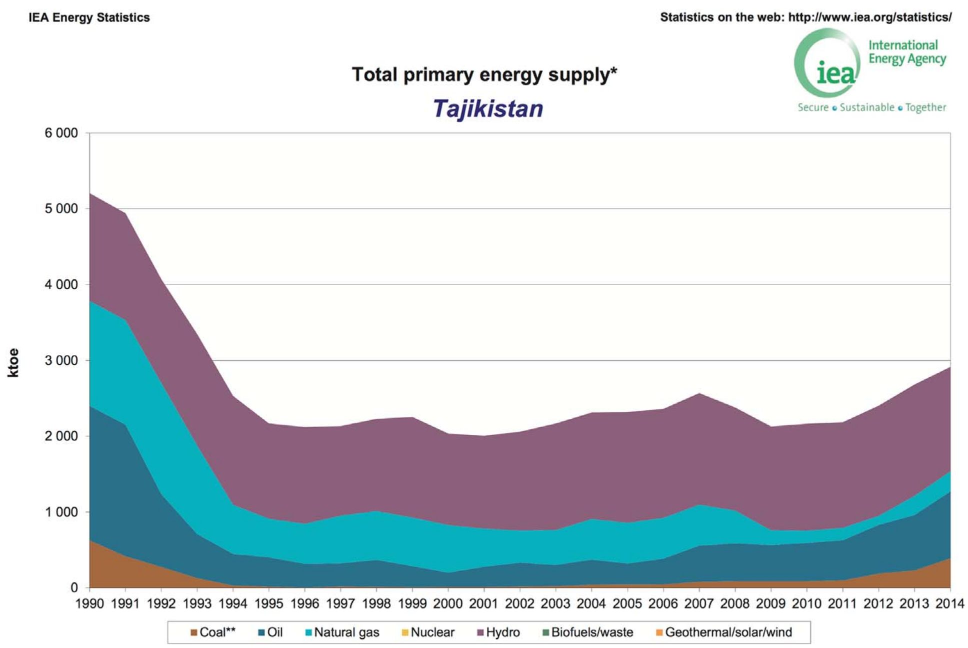

Fig. 1. Total primary energy supply, 1990–2014. *Source*: IEA Online Energy Statistics Database, 2014. Note: Following the collapse of the Soviet Union in 1991 the volume of energy supply in Tajikistan shrank by about half in three years. The total supply has not increased much since, but the share of fuels in the supply shifted towards greater dependence on hydropower.

Based on Practical Action (2014) work, *energy services*[2] can be conceptualized as energy relative to services that it can provide to people. Energy needs, then, are framed as a range of services that can be provided by tapping on different energy sources. As such, energy needs/services are stratified in terms of their immediacy to basic survival necessities of people: *for households, for earning a living,* and *for community*.

Using a novel *vulnerability* approach, this paper assesses threats and responses to Tajikistan's energy system, and it applies an analytical lens, using the four risk factors (natural, technical, political, economic) to reveal critical shortcomings that can be detrimental to energy security if not addressed adequately. Massive shortages of key energy carriers, such as electricity, natural gas, and fuel, such as gasoline and diesel, have crippled efforts aimed at achieving greater prosperity for the people of Tajikistan. Alleviation of such energy shortages and providing "reliable and high quality access to energy for the entire population, for industries and services, and to ensure the efficient use of energy in order to reduce poverty" are the main objectives of energy security in Tajikistan (Energy Charter Secretariat, 2010, p. 11). To achieve this goal, three major proposals have been advanced by the World Bank (Fields et al., 2013), the United Nations Development Program (Bukarica et al., 2011; Morvaj et al., 2010a, 2010b), and the Government of Tajikistan (Open Joint Stock Company 'Rogun HPP, n.d., Rogun HPP, n.d.).[3] Although these proposals are dated (2013, 2010/11 and 2008 respectively), they represent the existing options because no new alternatives to energy policy have been proposed. At stake is people's wellbeing, and therefore, it is important to assess their contribution to achieving energy security in Tajikistan. An evaluation of these proposals shows that they overlook the complexity of the energy needs and the role of local communities in addressing their energy priorities. As a way to remedy these shortcomings, we will recommend an alternative approach to energy security, namely the *energy services* approach based on Practical Action (2014) work. This approach requires a refocus from energy *sources* to *services*, which helps avoid the trap of accounting for energy stocks at the expense of meeting people's needs. Such a paradigm shift, facilitated by combining a *vulnerability* and *energy services* approaches, will inform effective policy to achieve energy security.

2. An overview of energy security in Tajikistan

This section provides an overview of the energy situation in Tajikistan by taking stock of energy sources and analyzing energy production and consumption patterns. This analysis provides the necessary context, in which to place the subsequent evaluation of energy security options provided in the following section.

2.1. National supply

For those unfamiliar with the country, the total primary energy supply (TPES) for Tajikistan in 2012 equaled 2805 kilotons of oil equivalent (ktoe) and was comprised of hydropower (47.2%), oil (30.3%), coal (13.4%) and natural gas (9.1%) (IEA, 2014a). According to Musayeva et al. (2009), hydro resources in Tajikistan hold a substantial power generation potential that is estimated at 527 billion kilowatt-hours (kW h), but technical potential is 317 billion kWh, or 60% per year. This ranks Tajikistan eighth in the world (EDB, 2008), second in electricity per capita worldwide (Fakirov, 2012), and first in the world in its hydropower potential. For hydrocarbons, the endowments for coal are estimated at about 4.452 billion tons, for gas, 8.517 trillion cubic meters, and for oil, 117.6 million tons (Musayeva et al., 2009). Recent reports of discovery of large reserves in the Bokhtar region of Tajikistan claim as much as 114 trillion cubic feet of gas and 8.5 billion barrels of oil (Collins and White, 2013). Recoverable oil potential is estimated at 27 billion barrels (EurasiaNet, 2012). However, domestic production only meets 16% of the national demand for coal,

[2] This concept is reviewed by Fell (2017) who finds a distinction between the desired end service or state and the energy service used to provide it, and formulates a new definition: "Energy services are those functions performed using energy which are means to obtain or facilitate desired end services or states." The PPEO 2014 approach is in line with Fell's (2017) finding and definition.

[3] Abbreviations: CAPS – Central Asian Power System; CASA-1000 – Central Asia South Asia Electricity Transmission and Trade Project; CHP – Combined Heat and Power (plant); EDB – Eurasian Development Bank; EE – Energy Efficiency; GBAO – Gorno-Badakhshan Autonomous Oblast; GDP – Gross Domestic Product; GW – Gigawatt; GWh – Gigawatt hour; HPP – Hydropower Plant; ICT – Information and Communication Technology; IEA – International Energy Agency; km – kilometer; km^2 – square kilometer; km^3 – cubic kilometer; ktoe – kiloton of oil equivalent; kW – kilowatt; kWh – kilowatt hour; MW – Megawatt; NGO – Non-governmental Organization; PPEO – Poor People's Energy Outlook; PV – Photovoltaic; RES – Renewable Energy Sources; RFE-RL – Radio Free Europe Radio Liberty; sHPPs – small-scale Hydropower Plants; TALCO – Tajik Aluminum Company; TPES – Total Primary Energy Supply; UNDP – United Nations Development Program.

4.7% of the demand for oil, and 5.4% of the demand for gas (Musayeva et al., 2009, p. 4).

The historical record of energy supply (Fig. 1) shows that Tajikistan's energy supply was highest in pre-1990 period, when it was part of the Soviet Union, and supply was relatively balanced among sources. A sharp decline occurred during the early 1990s, after the break-up of the Soviet Union and ensuing civil war in Tajikistan that devastated the economy in a matter of a few years. After signing the peace and reconciliation act in 1997, and in the first decade of 2000, overall supply levels fluctuated around 2500 ktoe, and more recently exhibited an upward trend. The energy mix, however, gradually shifted, with gas supply, once accounting for a larger share in the mix, decreasing over time. Concurrently, oil supply has shown a slight upward trend, owing to increased imports to power a greater number of private vehicles. The supply of coal also has made a gradual comeback due to demand for heating and use in combined heat and power (CHP) plants. Likewise, the share of hydropower supply has increased since mid-1990s to compensate for the reduction in the share of other fuels.

According to the Ministry of Energy and Industry of Tajikistan (2007; see also Musayeva et al., 2009), hydropower plants claim over 90% of the total installed electricity generation capacity in Tajikistan, with the remainder provided by thermal power plants. The Nurek Hydropower Plant (HPP) is the backbone of the energy sector in Tajikistan, generating 3000 megawatts (MW), or over 60% of all installed hydropower capacity. Other significant plants include Sangtuda-1 HPP (670 MW) and Baipaza HPP (600 MW). However, installed capacities are not fully utilized because their availability depends on river flows and effective demand. An estimated 71–81% of the capacity is available, and only 53–68% is actually operating on average. According to Fields et al. (2013), operating capacity is lowest in winter due to reduced river flows, with an estimated total firm capacity[4] of 2250 MW, which is 47% of peak load demand. Winter flows affect small hydropower plants even worse due to the absence of water storage facilities, and the firm capacity drops down to 25% of installed capacity in this season.

Winter shortages, due to lower river flows and reduced hydropower production, along with an increased demand for heating, and lack of affordable alternative energy sources, create a deficit between supply and demand that results in load shedding. According to Fields et al. (2013), the size of unmet demand for electricity was estimated at about 2700 gigawatt-hours (GWh), or 24% of total electricity demand in 2012. The associated economic losses from electricity shortages are estimated at over $200 million, or 3% of GDP every year. Social costs also arise from burning wood and coal, which cause indoor air pollution and are often insufficient to maintain adequately warm temperatures in homes and schools. This can adversely impact human health, particularly for women and children. Without a solution, winter demand is expected to exceed 15,000 GWh by 2020, and 45% will not be met, exacerbating hardships that people endure each winter (Fields et al., 2013).

2.2. Regional energy trade

The five countries of Central Asia – Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan and Uzbekistan – have substantial natural resources, including land, water, oil, gas, and mineral resources. As the highlights in Table 1 indicate, over 90% of fossil fuels are found in the territories of Kazakhstan and Uzbekistan, whereas over 90% of the hydropower potential rests with Kyrgyzstan and Tajikistan (Sharma et al., 2004). The difference in resource distribution hints at mutually beneficial cooperation in resources sharing. As part of Soviet Union, the upstream republics of Tajikistan and Kyrgyzstan exported hydroelectricity during summer to downstream republics of Uzbekistan and Kazakhstan, which compensated their upstream neighbors during winter with coal, gas and electricity, produced at thermal power plants (Sharma et al., 2004). Tajikistan produced about 40% and imported 60% of its energy in 1990 (IEA, 2014b).

Following disintegration of the Soviet Union, the countries began to shift in the political-economic domain away from centralized rule and command economy towards independence and market relations, which led to deterioration of regional energy sharing mechanism. Electricity trade was adversely affected; imports fell by 56%, from 3.9 billion kWh in 1990 to 1.7 billion kWh in 2000, and exports plunging by 85% in the same period (Sharma et al., 2004). Since 2008, piped gas supply from Uzbekistan, the sole supplier accounting for about 95%, decreased significantly (Fig. 1), because of overdue payments (Khashim, 2009), and stopped altogether at the end of 2012 due to disagreement over its import price (Swinkels, 2014). The Central Asia Power System (CAPS) that transmitted 1500 GWh of electricity was severed in 2009 (Fields et al., 2013), following disputes over each countries' share of electricity. The significant reduction in electricity trade meant that Tajikistan had to struggle through cold winters without adequate power supply. Not only did the economy suffer, but extreme hardships were imposed on the population. The relations further strained when Tajikistan resumed construction of Rogun HPP[5] to meet winter demand (Shahbazov, 2017). However, the summer excess hydropower capacity in Tajikistan, thus, remains mostly idle. The loss to the economy of idle discharge of water from power plants is estimated between $90 and $225 million a year (Fakirov, 2012). To remedy the situation, Tajikistan looked south to Afghanistan and north to Kyrgyzstan for energy cooperation. In 2016, exports to Afghanistan and Kyrgyzstan were 1.3 billion and 0.1 billion kWh respectively, comprising 8% of total electricity generated in Tajikistan (AsiaPlus, 2017). The export capacity is to expand through the Central Asia South Asia Electricity Transmission and Trade Project (CASA-1000) – a $1.7 billion investment in power transmission lines and convertor stations (World Bank, 2016) to channel 1000–1300 MW of electricity from Kyrgyzstan and Tajikistan to Afghanistan and Pakistan ("CASA- 1000 Project, 2011). In short, the ups and downs in regional cooperation present additional challenges to energy planners to optimize energy systems locally but also regionally.

2.3. National consumption

Industrial consumption of electricity more than doubled from 4.6 to 11.2 billion kWh in the decade of 1980s, when Tajikistan was part of the Soviet Union (Fig. 2). The increase was associated with the completion of the Nurek HPP, with 3000 MW installed capacity, along with rising demand from the aluminum smelting plant (now known as Tajik Aluminum Company, or TALCO) which expanded production, reaching a maximum of 457,000 metric tons in 1988 (TALCO, n.d.). Other large industrial projects, including a nitric-fertilizer plant in Vakhsh town, a chemical plant in Yavan town, and a cement plant in Dushanbe city also contributed to the surge in electricity consumption (TALCO, n.d.). Following independence from the Soviet Union, and subsequent political turmoil and through the 1990s, industrial production collapsed and its share of electricity consumption fell off from 60% to 35% of the country's total. Much was due to a reduction in aluminum production by about 40% from its peak. Simultaneously, electricity generation decreased from 18 billion to 14 billion kWh by the 1995–1998 due to (a) halting of Yavan Thermal Electric Power Plant that lacked fuel and maintenance, and (b) reduction of hydropower output potential

[4] "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" (Fields et al., 2013, p. 29).

[5] The Rogun HPP was started 1976 but construction halted after collapse of the Soviet Union in 1991. In 2004, a Russian aluminum company (RUSAL) agreed to complete construction but withdrew in 2007. Following a harsh winter energy crisis, in 2008/2009, the Government of Tajikistan announced resumption of construction that continues to date.

Table 1
Primary energy sources in Central Asia.
Source: Adapted from Sharma et al. (2004).

Energy Source	Unit	Kazakhstan	Kyrgyzstan	Tajikistan	Turkmenistan	Uzbekistan	Total
Crude Oil	MTOE	1100	5.5	1.7	75	82	1264.20
Natural Gas	MTOE	1500	5	5	2252	1476	5238
Coal	MTOE	24,300	580	500	Insignificant	2581	28,231
Total	MTOE	26,900	591	507	2327	4409	34,734
% of Total		**77.4**	1.7	1.5	6.7	**12.7**	100
Hydro Potential	GWh/year	27,000	163,000	317,000	2000	15,000	524,000
	MTOE/year	2.3	14	27.3	0.2	1.3	45.1
% of Total		5.2	**31.1**	**60.5**	0.4	2.9	100

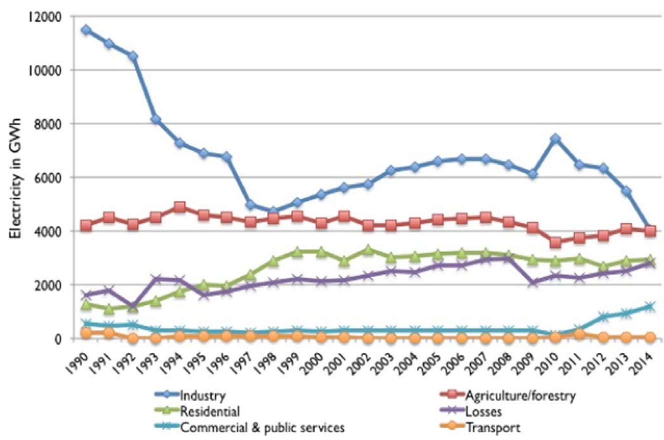

Fig. 2. Electricity consumption by sector.
Source: Authors' compilation based on IEA Online Energy Statistics Database, 2014. Note: The industry sector suffered greatly from lack of energy inputs after the fall of the Soviet Union in 1991. Other sectors have increased their consumption of energy, albeit by a small margin.

because of silting at Nurek HPP, along with closing several plants because of lack of spare parts and adequate maintenance (Sharma et al., 2004).

The use of electricity for agriculture was on the rise from 1980 to 1994, but then gradually declined, until 2010, after which it has steadily increased (Fig. 2). During the first period of increase, the operation of Nurek HPP provided more electricity for water pumping stations and also made more water available for irrigation, owing to its large reservoir capacity (10.5 km^3 – full and 3.2 km^3 – useful volume) (Barki Tojik, n.d.). Indeed, the primary function of Nurek HPP was to store water during the non-vegetative season and release it for irrigation during the growing season. Electricity production was considered a useful bi-product (Fields et al., 2013). The subsequent decline was related to a reduction in electricity output and reduced allocation to the agricultural sector because TALCO began to recover and increased its consumption of electricity (TALCO, n.d.). Additionally, ageing agricultural infrastructure, lack of spare parts, and access to fuels to run agricultural machinery contributed to lower electricity demand. More importantly, agricultural reform in Tajikistan introduced a series of dramatic changes regarding the use of land (Lerman and Sedik, 2009). Large unprofitable farms (*kolkhoz* and *sovkhoz*[6]) were restructured into a new form of organization called *dekhkan (peasant)* farm, which were of three types: individual, family, and collective ("partnerships"). The changes did not improve efficiency of the farms, because they continued to function like their predecessors. However, the decrease in land area sown to cotton likely resulted in reduced electricity consumption. Because cotton is water-intensive, less cotton sown meant less water pumped, and thus, less power consumed.

Household (residential) consumption of electricity gradually grew from 1980 to 2014 (Fig. 2). Between 2008 and 2009, there was a sharp drop in consumption. This was a time of severe energy crisis, with extremely low temperatures and heavy snowfall in winter, coupled with disruption of electricity imports from Turkmenistan, and gas imports from Uzbekistan. Electricity was rationed at 2 h a day for rural consumers, while in the capital city, blackouts stretched to 9 h a day. Households were desperate for wood, coal, paper boxes, and other materials to cook their food outdoors and stay warm by the fire. Offices were closed, surgeries suspended, and water supply was disrupted when pipes burst under the pressure of cold. In addition, maternity hospitals reported the tragic death of newborns (Laldjebaev, 2010). This was by far the greatest evidence of the failure of the resource sharing mechanism since the countries' independence, underscoring the deteriorating relations between Tajikistan and Uzbekistan. Since 2010 the situation has become exacerbated by the debate over water and electricity, particularly revolving around Tajikistan's proposed, contentious Rogun HPP project.

The spatial distribution of electricity consumption reveals that Dushanbe city dwellers use a substantially larger share than rural households, likely because electricity in the city is the sole energy source to satisfy primary needs of lighting, cooking and heating. In contrast, rural households resort to using solid biomass for cooking and heating needs in the absence of electricity. For all of Tajikistan, the seasonal pattern of consumption follows the availability of electricity dictated by the nature of hydropower production.

Other factors contribute to issues of affordability and equity in determining levels of consumption, including tariffs and electricity losses. Although tariffs (Fig. 3) are considered among the lowest in Europe and Central Asia (Fields et al., 2013; Swinkels, 2014), residential consumers (1.9 US cents/kWh) are charged the second highest price after commercial consumers (4.9 US cents/kWh) , while pumped irrigation (0.7 US cents/kWh) and TALCO (1.1 US cents/kWh) are charged less than households (Chorshanbiev, 2017). The tariffs may be low compared to other countries, but they are not affordable, especially for rural households (comprising 70% of the population) who spend an average of 10–15% of their income on energy, and the poor and extreme poor spend a whopping 19–24% (Swinkels, 2014). To cope with high energy expenses, households save money on food, clothes, reduce electricity use, live in one room, and rely on biomass – which adversely impacts their wellbeing (Swinkels, 2014). In addition, there are sizable electricity losses, on par with overall household consumption (Fig. 2). This is partly due to ageing energy infrastructure (Ergashev et al., 2013) and energy-intensive production of aluminum at TALCO. The other part is due to economic losses in terms of low tariffs, low collections and chronic indebtedness of the state-owned electricity utility, Barki Tojik (Fields et al., 2013; Swinkels, 2014). Inequity is heightened by winter energy shortages, which have now become a pattern, due to the seasonality of hydropower plants. To get out of this cycle, the government of Tajikistan is aiming at building new power plants, and upgrading existing ones.

[6] Kolkhoz – from "kolektivnoe khozyaistvo" meaning "collective farm"; Sovkhoz – from "sovetskoe khozyaistvo" meaning "soviet farm".

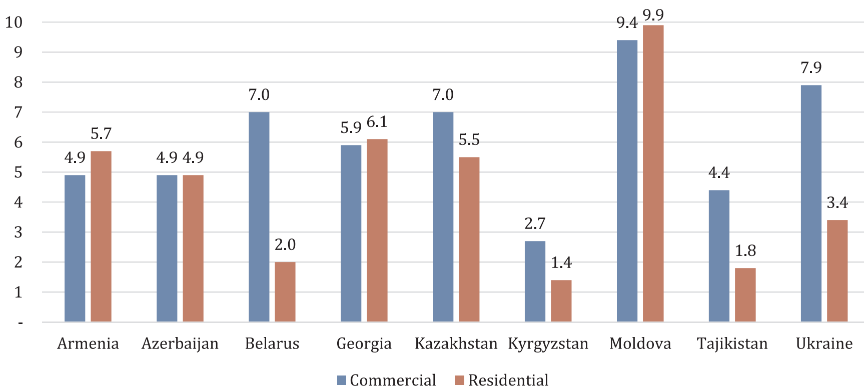

Fig. 3. Electricity tariffs (euro cents/kWh) in selected former Soviet Union countries (2013).
Source: Authors' compilation based on Swinscoe et al. (2015).

Table 2
Energy system vulnerabilities of Tajikistan by risk factors.
Source: Authors' compilation based on analysis of energy situation in Tajikistan.

Natural	Technical	Political	Economic
Melting of glaciers due to climate change threatens long-term water availability for hydropower	Insufficient production capacity resulting in energy shortages	Inadequate transparency undermines trust (e.g. of investors), and masks corruption	High cost of imports leads to energy shortages
More frequent and severe avalanches, landslides, floods and other hazards threaten supply networks	Dwindling infrastructure resulting in technical losses and supply failures	Problems with regional (transboundary) cooperation over energy-water sharing leads to spillover effects to other economic areas	Economic losses (e.g. low collection rates) undermines utilities' financial sustainability and prevents upgrading of infrastructure
Severe cold in winters increases demand for heating, damages infrastructure, and results in shortages	Lack of qualified specialists impedes uptake of state-of-the-art knowledge and expertise	Energy shortages may lead to disenfranchisement and political unrest	Inadequate financial resources hinder energy sector development

2.4. Energy security and vulnerability

The prospects for achieving energy security in Tajikistan depend, in part, on the country's energy system vulnerabilities, especially within the two major sectors of the energy system: electricity and fuel (including coal, oil and gas). Key vulnerabilities of the energy system in Tajikistan are revealed using the four risk factors (Table 2).

The government of Tajikistan has taken steps to address these vulnerabilities, including plans and projects to build small, medium and large hydropower plants for domestic demand, but also to sell power abroad. As discussed, existing thermal power plants are switching to coal, and new ones are under construction, primarily aiming at providing for heating needs in the winter. Development of new coalmines is also proposed and discovery of potentially large resources of natural gas and oil is attracting attention for further exploration and seismic surveys. International players are also involved, but the prospects of actual extraction remain uncertain. For the short term, fuel imports are likely to remain as a primary option in powering the transportation and industry sectors. Increases in electricity tariffs in July 2014, November 2016 and again in October 2017 are aimed at achieving greater efficiency and bolstering financial sustainability of electricity sector. Yet, affordability of tariffs for the households and small businesses remains uncertain.

Viewing the government responses through the vulnerability lens, it is evident that most efforts are concentrated on addressing the technical and partly economic factors, mainly through expanding domestic production capacity and tariff increases. Other factors remain largely unaddressed. Current national policy falls far short of securing energy access in rural areas of Tajikistan, and rural households remain vulnerable to energy shortages, and the related negative consequences of energy poverty.

3. Energy security in practice: moving beyond traditional pathways

Three sets of options, or pathways, for achieving energy security in Tajikistan have been presented by the World Bank, the United Nations Development Program, and the Government of Tajikistan. Weighing the different plans through the lens of risks and vulnerabilities highlights a collection of advantages and shortcomings of each plan and creates a foundation for an alternative way to provide energy security based on a new conceptual framework of *energy services* (Practical Action, 2014), discussed in the next section.

3.1. The World Bank pathway: efficiency, thermal supply and trade

The electricity system in Tajikistan "is in a state of crisis", claimed a recent World Bank report[7] (Fields et al., 2013). In an attempt to address the crisis situation, the World Bank study identifies a range of measures that could bridge the energy gap and put the country on the path towards long-term energy security. The actions are grouped under four categories: energy efficiency, investment preparation, trade promotion, and energy policy.

Energy efficiency measures include a pricing mechanism, particularly an increase in average tariff from \$0.0225 in 2012 to \$0.07 per kWh of electricity consumed by 2025. A sizeable contribution to efficiency also comes from reducing losses in transmission and distribution networks, estimated at around 18%. Further savings would come from implementation of energy efficiency measures at TALCO, along with switching from electricity-based to coal-based (and subsequently to gas-based) heat supply to urban households via centralized district heating systems. These efficiencies could yield about 20% reduction in

[7] Unless otherwise indicated, all data in Subsection 3.1. are taken from the World Bank report.

electricity demand.

Investing in new generation capacity through building of three new thermal power plants (3200 GW) and Sanobad run-of-river hydropower plant (500 GW) could also curb winter demand by 25%. Both thermal and hydropower plants require substantial investment of about $2.8 billion, and funding is required to maintain existing hydropower capacity, particularly to rehabilitate the Nurek HPP. Undoubtedly, a sound investment plan is needed to manage the large amount of capital required for the proposed actions.

Simultaneously, revitalizing the energy trade with Uzbekistan and Turkmenistan, and expanding trade with Afghanistan could lead to greater energy security. To begin, plugging back in to the Central Asia Power System (CAPS) is technically as easy as reconnecting the lines that previously transmitted around 1500 GWh of electricity to cover winter energy need in Tajikistan. Moreover, Tajikistan would be able to sell more of its summer surplus to Afghanistan, and even Pakistan, as envisaged by the Central Asia South Asia Electricity Transmission and Trade Project (CASA-1000). Along with electricity trade, imports of natural gas from Uzbekistan, which were halted in 2012, could be reinstated and even expanded given the gas trunk line capacity of 7 billion cubic meters. To resume imports, mutually agreeable terms on price and delivery schedules are necessary.

Combining all of the above measures under a robust energy policy is arguably the most important action proposed in the study. Such a well-rounded policy would balance domestic energy needs with export and import potential, so foreign exchange can be earned, while every home remains powered. In this balance the role of new power plants, both thermal and hydro, would be adequately laid out so that the need for power is met economically according to acceptable social and environmental standards. With potentially promising reserves of domestic natural gas, the way forward would be to accelerate exploration efforts. In addition, rates would be affordable, and social safety nets designed as necessary. In economic terms, these measures would cost over $3.4 billion, requiring an average of about $380 million annually from 2012 to 2020. In this plan, about half of the financing goes to addition of new capacity, with rehabilitation accounting for a third, and the remainder going to efficiency and construction of power export transmission lines. To put the figures in perspective, the investment required makes up about 5% of the average GDP annually. All in all, the proposed actions signify major changes to the energy system of Tajikistan, carrying the hope of greater energy security.

The World Bank's plan to resolve the winter energy crisis is compelling; however, several issues need addressing. As the study recognizes, costs represent the most significant financial risk and would require careful consideration of tariff policies, private sector involvement and donor assistance, as well as potential earnings from power exports to mitigate the risks (Fields et al., 2013). Additionally, social and environmental costs also would require mitigation.

Tariff increases proposed in the plan, although estimated to be in line with consumers' willingness to pay, would be difficult to implement. The study estimated annual increases at around 11%, between 2014 and 2025, but such an increase would further impact already strained household budgets. Against a background of severe energy shortages increases would create additional burden, particularly for the poorer consumers, unless a safety mechanism is designed and properly enforced. Tariff increases also have serious political implications. For example, in neighboring Kyrgyzstan, increases in utility rates played a major role in massive protests that allegedly led to overthrowing of the government on April 8, 2010 (Kramer, 2010).

Similarly, private sector involvement in the energy sector would face difficulties, requiring substantial effort to improve the overall business climate in the country. According to Ease of Doing Business report in 2013, Tajikistan ranked 143 out of 189 economies worldwide, which is much lower than neighboring Kyrgyzstan (68), although they are similar in population, geography and resource endowments (World Bank, 2013). Complicated procedures to start a business coupled with myriad regulations increase costs and uncertainties, thus deterring entrepreneurs and investors to enter the energy market. The experiences of foreign-owned Sangtuda-1 and Sangtuda-2 HPP with non-payments, and lack of private investments in Rogun HPP (except the forced purchase of shares by population) are prominent examples of unfavorable business conditions.

Indeed, export potential of electricity is high during the summer months when river flows are high and surplus is generated at hydropower plants. However, since Tajikistan's electricity network was severed from the CAPS in 2009 the summer excess capacity remains mostly idle. Only a small fraction is exported to Afghanistan. The recommended reconnection to and revitalization of electricity trade among Tajikistan, Turkmenistan and Uzbekistan would be very difficult especially in light of poor political relations with Uzbekistan, particularly stemming from fierce opposition to the construction of Rogun HPP. Notably, the climate of tense relations was a contributing factor to halting of gas supplies from Uzbekistan in 2012.

Given the dim prospects of regional energy trade, domestic resources of coal become attractive. The proposal for fuel-switching to coal-based heating, however, brings with it increased emissions and air pollution and associated health and environmental impacts. The Dushanbe-2 thermal power plant considered in the World Bank study was inaugurated on January 10, 2014. Many had raised concerns over negative impacts on the environment and human health, given the plant's location within 2 km of a residential area, a children's amusement park, and botanical gardens. Authorities assured that the plant would make use of modern, clean and efficient technologies that reportedly capture hazardous emissions to 99.8%. However, soon after operation, reports emerged of citizens complaining about a thick layer of coal dust on their property and black soot spoiling laundry hung outside (AsiaPlus, 2014; Kalybekova, 2014; Sodiqov, 2014). Following the early complaints, plant operation was stopped for 24 h, after which the issue was dismissed as a one-time release. Although particulate matter may be better captured with improved filters, emissions that are not easily traceable (e.g. CO_2, SO_x, NO_x and mercury) would be much harder to deal with. The associated social and environmental costs from these emissions could counter the benefits of warmth and comfort for city residents. Furthermore, these costs could exacerbate the financial impact of increased tariffs on household budgets.

TALCO may be able to implement some of the efficiency measures; however, the shifting of maintenance to wintertime may not be technically feasible due to specificity of aluminum production processes. Moreover, the company may be constrained by its long-term contracts with suppliers of raw materials and buyers of manufactured products. These actors determine the time and volume of production that may conflict with the suggested transfer of repair works from summer to winter. To date, there is no indication of any such actual measures put in place by the company.

In short, the proposed plan for addressing winter energy shortages identifies some important aspects of energy policy in Tajikistan. The extent to which the proposed solutions are feasible is subject to debate, because they partly address technical and economic but underestimate political and ignore natural risk factors.

3.2. The UNDP pathway: affordable renewable energy for rural and vulnerable households

The United Nations Development Program prepared a set of three documents that address energy sector challenges in Tajikistan and propose solutions towards "ensuring reliable and affordable energy supply as a main prerequisite for enhanced economic development and reduction of poverty" (Bukarica et al., 2011, p. 2). The foci of these documents are: to deploy renewable energy sources (RES), and to improve energy efficiency (EE). The financial mechanism to implement the proposed measures is identified as the National Fund for RES and EE.

In the first document, the Intermediate Strategy (Morvaj et al., 2010a), priority is given to community-based small-scale hydropower plants (sHPPs); solar energy, in terms of thermal collectors and photovoltaic devices; and some low cost energy efficiency measures. The second document, the National Program (Morvaj et al., 2010b), makes a case for nation-wide scaling up of the measures proposed in the Intermediate Strategy. The program would reach 100,000 vulnerable households, providing each with access to a minimum of 1 kW of electricity.[8] Installation of sHPPs that produce 200 MW for the duration of the program, until 2020, would require an estimated $110 million. For social institutions, including hospitals, schools and kindergartens, installation of solar photovoltaic (PV) and solar thermal systems (for hot water) is recommended in this plan.

The third document, the Energy Efficiency Master Plan (Bukarica et al., 2011), proposes a range of policy measures to strengthen the legal and regulatory standards of energy use, as well as institutional capacities to oversee implementation of energy efficiency activities. The plan includes actions to revitalize district heating systems and curb transmission and distribution losses, thus improving energy supply. At the demand side, the actions address various aspects, ranging from building codes, to energy equipment standards, to energy audits, training and education, and metering and billing. Other efficiency measures include insulation of buildings by using local resources (straw and cane), technologies (lathing and furring), installation of double glazed windows, and improving cooking/heating stoves. Energy savings from this plan gained by 2020 are estimated up to 895 GWh equivalent to 3.6% of Tajikistan's total final energy consumption in 2011.

Solar energy would require at least a $50 million investment, with an additional $1.65 million for efficiency measures until 2020. Total costs for the sHPPs, solar energy, and efficiency measures were estimated at over $162 million for the period from 2010 to 2020. To provide for the suggested measures, the UNDP plan proposes establishment of the National Trust Fund for Renewable Energy Sources and Energy Efficiency in Tajikistan. This is a financial instrument that acts as an intermediary between energy producers (small-scale community based hydropower plants) and the utility (Barki Tojik) that essentially bridges the price differential between an incentive price guaranteed to the producer and the average system price of electricity. In essence, the system operator pays an average price to the Fund for electricity from the power producer, who receives a higher than average price from the Fund. During off-grid operation, the Fund also acts as intermediary between the RES power producer and final consumers – guaranteeing incentive price to the producer.

The three strategic documents produced by the UNDP propose some reasonable solutions towards achieving energy security through small-scale technologies and energy efficiency initiatives that would stimulate local economic development activity and reduce poverty in rural areas of Tajikistan. This proposal has many merits, but several key issues require further consideration.

The crux of the energy plan is development of sHPPs, and their connection to the national electricity grid. Tajikistan's mountainous landscapes and availability of streams and rivers make this plan attractive. However, the proposal does not examine the potential for hydropower production in terms of availability of sufficient river flow in wintertime. Furthermore, there is no spatial analysis to identify where this potential could be realized. Resource availability does not always coincide with population centers and proximity to where electricity is needed is a major criterion for making sHPPs successful; the farther away the plant, the larger the losses in transmission (and distribution). Generation capacity also has to match the demand for energy in the service area. In theory, connection to the grid would be advantageous when energy supply from individual sHPPs exceed or fall short of demand. However, given the seasonal nature of electricity generation in the country, with system-wide surpluses during high flows and shortages during low flows, connection to the grid may actually offer little advantages. The grid will not offer a cushion because both small and large-scale hydropower plants follow the same production pattern. It would have been advantageous, had the grid been backed up by coal or natural gas fired power plants.

The program of national scale-up, as proposed in the UNDP documents, is indeed germane to addressing energy needs and improving the living conditions of approximately 1 million of the most vulnerable people in rural areas. The scale-up scenario, however, is based on a single project that was implemented in Vahdat district, in the outskirts of the capital city of Dushanbe. This raises questions regarding the applicability of the project experience to other communities. Importantly, it is not specified whether the pilot project was able to cover the energy deficit in the winter. Second, the geographic and environmental conditions (including water flows), and the pattern of demand in the project location are not specified. Therefore, it is difficult to ascertain how representative the pilot project was to other locations, where conditions can be drastically different. The landscape of the country spans highlands and highland valleys with low population densities, to lowlands with more dense settlement areas. Thus, the magnitude, timing, and patterns of energy needs of people in different areas would be vastly different. In addition, it is not clear, even in the pilot project, that all energy needs – including heating, cooking, lighting, information and communication, and earning a living – would be satisfied with the provision of 1–3 kW of electricity per household, along with some energy efficiency measures. At minimum, an analysis of energy needs at the household and community levels is a necessary first step toward developing viable energy options.

Other challenges to this proposal include relying on Barki Tojik as the system operator to purchase power from sHPPs. Acting as the single utility in charge of generation, transmission and distribution for the whole country (except GBAO region), Barki Tojik has faced difficulties in managing its activities along many fronts. A recent assessment of the company's financial performance revealed several inconsistencies (Kochnakyan et al., 2013), as it incurred large cash deficits that crippled its ability to perform required system maintenance and ensure domestic power supply. The shortfall was due to high system losses, low rates of collecting of payment for energy bills, high overhead expenses and other unclassified costs. Barki Tojik failed to make any debt service payments in 2011–2012, and by January 2013 had incurred $524 million in outstanding sovereign guaranteed debt, which accounted for 20% of Tajikistan's total public debt. Furthermore, the company faced difficulties in paying for the power purchased from the independent power producers, such as Sangtuda-1 HPP, which produces about 15% of annual electricity in Tajikistan. The failure of Barki Tojik to pay Sangtuda-1 HPP $84.8 million resulted in their inability to pay $10.9 million in taxes, and a threat by the government to freeze the accounts of Sangtuda-1 HPP, followed by a rescheduling of payments (Interfax, 2013). The UNDP documents explicitly emphasize timely payments for the operation of the National Trust Fund for RES and EE. If Barki Tojik, acting as the system operator and power purchaser from sHPPs is unable to pay its dues in a timely manner, it is unlikely to be a good choice as a purchaser of power from sHPPs.

Importantly, funding proposed by the UNDP for the RES and EE appear to be inadequate to meet the estimated costs of the plan. Namely, special charges for motor vehicles, imported vehicles, and a petroleum levy could reach about $334 million versus the expected cost of $162 million. This would mean that all the costs would be borne out by one sector of the economy. Apart from possible adverse impacts on mobility, reliance on a single source of financing is not in line with risk management practices. For example, fluctuations in prices of vehicles and gasoline would affect the demand for and supply of vehicles, and this would in turn translate into vulnerability for the RES sector.

In brief, the UNDP plan to improve energy access in rural areas

[8] Unless otherwise indicated, all data in Subsection 3.2 are taken from three UNDP documents.

through RES and EE initiatives presents a bottom-up approach to achieving energy security. Although the plan entails no major political concerns, its technical and economic foundations require further strengthening. Natural risk factors also need consideration.

3.3. The government of Tajikistan pathway: the Rogun Hydropower Project

After two consecutive years of energy crisis during the winters of 2008 and 2009, Tajikistan resolved to capitalize on its massive hydropower potential. The hope was to secure sufficient power for domestic use and to increase electricity exports to foreign markets. With 317 billion kWh per year of economically feasible potential, utilization was estimated at around 5% (EDB, 2008). It is this untapped potential that formed the basis of the government plan with the promise of breaking the country out of the recurring cycle of winter energy shortages.

In the government plan, the realization of Tajikistan's hydropower potential is centered on the construction and rehabilitation of a series of hydropower plants. The centerpiece of this plan is the Rogun HPP, with a dam projected at 335 m high and an installed capacity of 3600 MW. Rogun HPP is expected to satisfy the domestic demand for electricity, and anticipated to generate surplus for export to neighboring countries. With an annual generation of 13.1 billion kWh, together with Sangtuda 1 and 2 HPPs, the overall generation in Tajikistan will reach 33.5 billion kWh. This will exceed the projected domestic demand, creating a surplus of about 10 billion kWh, which can be exported (Gulov, 2007, p. 23). Furthermore, Rogun HPP is designed like the existing Nurek HPP to serve the dual purpose of electricity generation and water storage for irrigation. Hence, the flows out of the reservoir will be conditioned, ideally, to achieve both objectives.

Although hydropower is alluring, along with the prospective benefits, large hydropower facilities are also accompanied by complex geopolitical, social and environmental impacts. For example, there is a strong opposition by Uzbekistan – Tajikistan's downstream neighbor – against construction of the Rogun HPP. Uzbekistan is concerned that the accumulation of water in the reservoir will lead to further lowering of the Aral Sea, which will exacerbate environmental problems in the region. Another possible source of concern is the potential for Tajikistan to turn off the tap and leave the large agricultural fields of Uzbekistan without water at any time. The estimated resulting loss from agriculture would be $600 million annually (Jalilov et al., 2011).

In addition, there are tremendous social impacts associated with relocation and resettlement of the population from the inundation zone. Despite the attempts to make necessary provisions for resettlers, a news agency reported tens of thousands of people refusing to leave their place of residence (Ismonkulov, 2011), while some are dissatisfied with the compensation offered by authorities, claiming it does not reflect the market value of their property and is not a sufficient amount to build a new house. Another group is opposed to the project because the reservoir is going to inundate graveyards where relatives are buried. Noting the absence of a resettlement plan and inadequate preparation by authorities in the resettlement project, Sodiqov (2009) observed that the situation of the newly resettled families "resembles a spontaneous refugee camp" (p. 17), where people lack basic sanitary conditions and are uncertain when they would receive the materials to build houses and move out of tents. Moreover, relocated people are not accustomed to a more humid and warmer climate, and are unfamiliar with cultivation of cotton, as opposed to their traditional agricultural crops of wheat and potatoes.

In response to these concerns, and in an effort to facilitate informed decision-making, the government of Tajikistan, with financial backing from the World Bank, commissioned independent evaluations of the Rogun HPP in 2010. The evaluations, which span technical, economic, social and environmental aspects, were completed and final reports were disclosed in September 2014. The World Bank (2014) released a note highlighting key issues in the assessment reports, and called attention to further related concerns. Effectively, the assessments were positive and gave green light to construction of the Rogun HPP, with some suggested modifications. The position of Uzbekistan, nevertheless, remained unchanged. After the conclusion of the fifth and final round of riparian consultations in July 2014, the First Deputy Prime Minister of Uzbekistan officially stated that the findings were "completely unacceptable", because Uzbekistan's concerns over international safety considerations, transboundary water management and related socio-economic issues were not adequately addressed, and that "Uzbekistan never, and under no circumstances, will provide support to this project" (Azimov, 2014).

Although estimates put the cost of the Rogun HPP from US$3–5 billion (Forss, 2014), or about half of Tajikistan's annual GDP, the project is claimed to be a silver bullet solution that would resolve all energy shortages and also support the country's economic development. However, facing a stalemate in bilateral relations and limited prospects for financing, the government of Tajikistan is struggling to realize the Rogun HPP project. The project has now taken a life of its own, elevated to the status of "symbol of the nation" and a "national idea" (Suyarkulova, 2014). In other words, tied to the project is massive political baggage that goes beyond economic and technical considerations.

Nonetheless, in October 2016 the main riverbed of Vakhsh River was blocked to officially launch the construction of the Rogun dam that will be undertaken by an Italian construction conglomerate Salini Impregilo under a $3.9 billion contract (REF-RL, 2016). This development came after the death of the Uzbek president Islam Karimov in September 2016 and neither the newly elected president Shavkat Mirziyoev, nor other government officials made public comments about the launch. Although a delegation from Uzbekistan visited Tajikistan in January 2016, it is unknown whether a shift in bilateral relations is underway.

This state of uncertainty, coupled with aforementioned socio-economic and environmental concerns, confounds the prospects of materializing the anticipated gains from increased electricity generation. Therefore, multiple interacting issues need to be tackled – which require sophisticated technical expertise, mitigation of political and economic risks, and consideration of natural risks (e.g. Rogun depends on glacier water).

In sum, mapping the three pathways against vulnerability factors shows that *technical* and *economic* prevail over *natural* and *political* considerations (Table 3). As discussed above, even the technical and economic aspects present additional challenges that are overlooked. This analysis provides evidence that the *vulnerability* framework helps to uncover the neglected aspects of energy policy. Granted, the *dimensions* approaches could arrive at similar conclusions; however, they could not directly point to political factors, which is arguably the most critical ingredient of energy security deliberations.

4. Energy services: an alternative pathway and policy paradigm

The three proposals evaluated here present different sets of options for achieving energy security in Tajikistan. The action plan proposed by the World Bank study (Fields et al., 2013) emphasizes eliminating nationwide winter energy shortages; the UNDP (Bukarica et al., 2011; Morvaj et al., 2010b) highlights alleviating energy poverty in rural areas; and the government of Tajikistan's Rogun HPP project aims at generating enough electricity to meet domestic demand and export surplus to neighboring countries. The World Bank and UNDP plans are intermediate-term strategies, focusing on energy efficiency measures and technologies other than large-scale hydropower by 2020. The Rogun HPP is more complex and costly, but is designed for the long term. All of these options can potentially meet winter energy requirements, but, only if substantial and sufficient funding is generated (Table 4). Furthermore, none of the proposals take the *energy services* approach in their analyses.

Although they recognize that energy is needed for some purpose the

Table 3
Consideration of vulnerability factors in three pathways.
Source: Authors' compilation based on analysis of three pathways.

	Natural	Technical	Political	Economic
World Bank	Not considered	New generation capacity at thermal and hydropower plants; Transmission lines; Efficiency measures	Not considered	Efficiency measures, including tariff policy; Investments in new generation capacity and transmission; Regional energy trade
UNDP	Not considered	Small-scale hydropower, solar energy; Efficiency measures	Not a major issue	Low cost small-scale hydropower and solar energy; Efficiency measures, including insulation; Feed-in-tariff mechanism
Government of Tajikistan	Environmental impact assessments conducted by World Bank, but no remedies implemented	Large-scale hydropower generation	Transboundary disagreements receive rhetorical rebuttal, but no action to negotiate	Investment in large-scale hydropower; Income generation through regional energy trade

Table 4
Comparative Assessment of Three Tajikistan Energy Pathways.
Source: Authors' compilation based on: a) Morvaj et al. (2010b) b) Fields et al. (2013); c) Forss (2014); d) World Bank (2015). Note: The World Bank proposal and the Rogun HPP would be very costly compared to the country's GDP. Taken together, the short- and long-term plans require substantial amounts of investment that may need to come from both domestic and, potentially to a large extent, outside funding sources. Therefore international support and investment may be key to future energy security.

UNDP studies[a]	World Bank study[b]	Rogun HPP[c]	Tajikistan's GDP[d]
$162 million	$3.425 billion	$3–5 billion	$7.853 billion

three major plans do not fully address specific energy needs and uses of people. The World Bank proposal can be characterized as a conventional development approach to analyzing energy security issues. It takes a stock of how much energy is produced, derives a demand function that shows a gap with supply, and proposes a set of technical and economic solutions to close the gap. The proposal does not engage in further detail on how much of the energy is used for different purposes, such as heating, cooking, lighting, information and communication, or productive uses. Neglecting the use patterns runs the risk of miscalculating actual energy needs and the type of energy required for each purpose.

The UNDP proposal is closer to taking an *energy services* approach. With its focus on providing energy to rural households, the study discusses options to provide lighting and thermal comfort for homes (*energy for households*) and social buildings (*energy for community services*), as well as enabling some productive economic activity, such as operating small processing factories (*energy for earning a living*). However, it falls short of defining what is needed at the household and community level that could be addressed through some form of energy provision.

The Rogun HPP proposal is a one-size-fits-all approach that ambitiously attempts to address all energy problems at once. Indeed, if successful, it may ultimately provide physical access to electricity that is more reliable. However, it is highly unlikely to be an affordable solution to rural people, which would present another type of barrier. Furthermore, electricity alone cannot provide for the diversity of energy services needed and desired by all people. In addition, it is uncertain when the project will start generating electricity and when reliable and efficient distribution will reach all areas of the country. In the meantime, energy shortages will continue to keep people in poverty and quality of daily life will remain unchanged, unless alternative solutions are seriously considered.

Assessment of energy security is incomplete, if not misguided, without first understanding the nature of energy needs and the forms of energy that could potentially meet those specific needs. Therefore, a rearrangement is required to place energy services at the center of analysis and redraw the implications for Tajikistan. Such a shift in focus from *energy sources* to *energy services* can present an alternative approach to providing energy access in ways that also contribute to people's energy security, as well as individual and community well-being. In this transition, the role of local people in achievement of a better quality of life through acquiring access to energy becomes critically important. Therefore, policymakers should prioritize energy services in order to effectively address the multifaceted challenges of poverty alleviation and energy security.

To help guide this process, as Table 5 illustrates, a wide range of services from cooking to small business operations to industrial activities should first be differentiated and then addressed with appropriate technologies at each level and scale. There is a general misconception about the capacity of decentralized energy solutions; yet, evidence shows they do provide reliable and affordable service at a fraction of time and cost compared to grid extension (Practical Action, 2016). Rather than relegating them to the fringes of the grid, a concerted effort is required to integrate such technologies into the energy system. An important first step in this direction is to train staff in delivery of energy services using appropriate technologies for the energy, health, water, agriculture, and education sectors (Practical Action, 2016). Study tours to places where these technologies and approaches have been successfully implemented followed up with piloting as well as learning from existing experimental projects through rigorous measurement of outputs and outcomes, going beyond accounting for megawatts to "consider the numbers of jobs created, agricultural productivity increased, children educated, patients served per megawatt, and so on" (Practical Action, 2016, p. 4) could be the basis for a shift towards a service oriented energy provision.

Community participation in decision-making plays a key role in the success of development projects. We suggest that energy development planners not only ask "energy security by which technology," but "energy security for whom?" This reorientation of focus on service beneficiaries would require their involvement in energy planning and implementation. Rather than deciding at the national level what is appropriate for local communities, meaningful efforts should be made to understand the communities' energy needs and assist with technical expertise and financial support to meet their needs. We endorse the recommendation of the Practical Action (2016) that "[t]hose living in energy poverty should no longer be on the periphery of energy programs steered by energy security, infrastructure expansion, and economic growth. Instead they should be at the heart of the agenda, driving planning and policy" (p. 4). In fact, for many emerging economies pay-as-you-go solar and micro-grids are considered a new class of infrastructure investment that improves local livelihoods (BNEF, 2017).

Table 5
Summary of options that expand access to energy services.
Source: Modified from Laldjebaev et al. (2016, p. 108) and Practical Action (2014, p. 51). Note: The four options presented in this table provide for diversity of services at different levels and scales. They are not mutual exclusive and, therefore, can be complimentary if pursued alongside each other. There is no hierarchy among the options in terms of the services obtained as in the "energy ladder" model. Instead, each option has its own set of associated strength and limitations or vulnerabilities. Ultimately, none of the options can provide for all the services on its own. The underlying context of the service beneficiaries and their needs should take precedence when considering implementation of appropriate options.

	Conventional options	Off-grid technology	Micro-grids	Grid electrification
Level	Community and household	Household	Community	National, regional, and even international
Scale	Very small- to small-scale	Very small-scale	Medium-scale and small-scale	Large-scale, centralized capital intensive
Geographic radius	< 30 km^2	< 1 km^2	1–49 km^2	More than 50 km^2
Number of customers	Dozens to thousands	Usually a dozen or less	Dozen to hundreds	Thousands to millions
Installed capacity	Various	< 20 kW	20 kW to 10 MW	More than 10 MW
Investment required	Hundreds to thousands of dollars	Thousands of dollars	Millions of dollars to hundreds of thousands	Billions of dollars
Time to deployment	A week or less	Week to a few months	A few months to a year	Several years
Examples of technologies involved	Woody biomass, candles, dry cell batteries, kerosene lanterns	Individual solar home systems, pico-hydro units, improved cook stoves, residential wind turbines, home weatherization	Community-scale solar PV or biogas systems, micro-hydro systems	Large hydropower dams, grid extension, thermal power plants
Energy services enabled	Basic energy services: cooking and water heating, space heating, lighting, cooling, ICTs	Enhanced basic energy services with increased reliability, affordability, and reduced health risks	Enhanced basic energy services plus energy for earning a living and community/public services	Enhanced basic energy services, energy for earning a living and community/public services plus energy for industries
Examples of services enabled	Basic household and task lighting, space heating, cooking	Higher quality lighting, charging electronic devices, more efficient and less hazardous cooking, improved home comfort (heating/cooling)	Street lighting, small business lighting, refrigeration (e.g. of vaccines, food preservation), reduced drudgery/more time available for other activities, improved health and education outcomes, mechanized agriculture (e.g. solar powered irrigation) and improved agro-processing	Large-scale industrial and manufacturing productivity, income generation (e.g. via electricity exports), water for agriculture
Vulnerabilities	Higher exposure to indoor air pollution	Technology know-how	Technology know-how	Natural hazards, sabotage

In short, a change in policy paradigm towards energy services along with adoption of decentralized renewable energy solutions is taking shape globally, and it is prudent for the national energy planners in Tajikistan to learn from this process and make that change at home. Failure to do so risks keeping people in energy poverty and eclipsing their hopes for a better life.

5. Conclusion and policy implications

This paper applies the novel *vulnerability* approach advanced by Cherp et al. (2012) to assess the energy security situation in Tajikistan. This approach allows sufficient flexibility to identify existing challenges without sacrificing discussion of *dimensions* of energy security. With this in mind, we advance three conclusions, one related to the concept of energy security, and two related to policy.

First, the *vulnerability* approach constitutes two key ingredients in its definition of energy security. It provides a concise and comprehensive framework to evaluate energy systems based on four major risk factors: *natural, technical, political,* and *economic*; and it specifically includes provision of *energy services*. The latter is usually implicit, if not overlooked, in conventional approaches, which primarily focus on *energy sources* (e.g. availability, affordability of supply). However, as Laldjebaev et al. (2016) illustrate, energy sources or forms are not necessarily mutually substitutable to deliver a certain energy service. For example, certain staple foods that are cooked on biomass are nearly impossible to replicate in electric stoves. Instead of labeling them as socio-technical barriers to transition to highly efficient forms of energy (e.g. electricity), socio-cultural and ecological relevance of energy use should be viewed through the lens of the *services* that people derive from different sources or forms of energy. This understanding of services, then, should be incorporated into energy security discussions on par with the understanding of the risk factors. It is this combination of the two elements – services and risk factors – that is unique about the *vulnerability* approach. Adopting this approach to energy security assessment will help reveal the underlying causes of the problems, as we have tried to demonstrate in this paper.

Second, attention to vital energy systems and services adds nuance and depth to the current discussion over energy security problems, plans, and pathways to Tajikistan. When applied specifically to the country's most pressing energy vulnerabilities, our analysis reveals an intersection of threats including neglect of environmental conditions, lack of diversity in energy sources (overreliance on hydropower), shortfalls in production capacity, unreliable and expensive energy imports, crumbling and inefficient infrastructure, lack of transparency and accountability in energy provision, political stalemate in regional water and energy relations, and insufficient financial wherewithal to address the challenges. Although some of these vulnerabilities are recognized individually, their interactions are currently obscured or, worse, ignored in contemporary policy discussions. We maintain that cultural significance, ecological sustainability and suitability of technology for intended interventions should be given priority in addition to technical reliability, fuel costs, and pricing schemes (Laldjebaev et al., 2016). Community engagement and decision making is central to more progressive policy, and therefore, to eradicating poverty and achieving security – through provision of energy services.

Third, although three options have been recently proposed to improve the energy security situation—labeled the World Bank pathway, the UNDP pathway, and the Rogun HPP pathway—each approach is inadequate in its own way. A service-oriented plan is needed to provide energy access, and by doing so improve people's wellbeing. The *energy services* approach offers a potentially relevant way to first understand the energy use patterns, and then identify opportunities to effectively provide energy access. Capacity development of human capital at both the national and local levels is imperative to take advantage of decentralized renewable energy technologies. Following Practical Action's work, we also recommend involvement of actors from private and non-governmental sectors to help proliferate the service-oriented approaches. Indeed, the small-scale technologies are showing great promise elsewhere in terms of lower cost, suitability, and quicker deployment to meet energy needs locally (BNEF, 2017). While development organizations can help introduce some of the technologies, civil society organizations can facilitate community participation in energy planning. Government support is further required to incentivize the private sector through subsidies and tax breaks when the latter import new technologies. Laws and regulations will also need to be developed to determine property rights, e.g. for land use to install community solar or wind farms. Given proximity to China, a global leader in both solar and wind technologies production, advantageous terms of trade could be negotiated for private sector to import these technologies. Furthermore, training of specialists could be arranged along with study tours in China to bolster the adoption of new approaches. The focus on households and community needs as well as involvement of the civil society and private sector actors is at the heart of the service-oriented energy provision. Therefore, we strongly recommend their incorporation into the national level energy planning and policy. In sum, energy planners should collaborate with communities, civil society, and private sector to tailor energy projects to user needs aimed at reducing vulnerabilities, eliminating energy poverty, and improving people's livelihoods.

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