Strengthening Power System Security in Kyrgyzstan: A Roadmap

International Energy Agency

Co-funded by the European Union

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Table of contents

List of figures

List of boxes

List of tables

Executive summary

Kyrgyzstan's high dependence on hydropower exposes it to the risk of electricity shortages during periods of water scarcity. This risk is magnified by the growing fragility of the power system, which is in urgent need of generation and network investment to improve its operational reliability and to ensure that it has sufficient capacity to meet demand over time. The challenge is further amplified by rapidly growing electricity demand, fuelled by unsustainably low regulated electricity prices, which threatens to quickly outstrip domestic production capacity. Maintaining access to reliable electricity services is likely to become increasingly problematic in these circumstances, especially during periods of water shortage.

The government of the Kyrgyz Republic recognises these challenges and has initiated a range of investment initiatives to help address them. Policy responses to date have focused on addressing the longer-term adequacy dimensions of the power system reliability and resilience challenge. However, relatively little attention has been focused on the more immediate power system security challenges facing the Kyrgyz power system. Opportunities exist to implement a range of policies that could help to strengthen power system security in the shorter term, especially during periods of water shortage when power system reliability and resilience are likely to be under greatest stress.

A comprehensive and integrated policy framework will be needed to help strengthen power system security in a timely, efficient and cost-effective manner. This roadmap seeks to address this need. Its goal is **to help improve power sector reliability and resilience in Kyrgyzstan in the short term by quickly strengthening power system security, especially during periods of water scarcity.**

The roadmap seeks to deliver this goal by deploying an interrelated set of internationally proven and effective policy measures over the next decade that focus on achieving three strategic priorities:

- improving power system operation and management, especially in response to sustained hydrological events
- broadening and deepening supply-side capability to respond to sustained hydrological events
- developing complementary demand-side capability that can be deployed quickly and effectively during sustained hydrological events.

Measures proposed to improve the system operator's capacity to manage significant losses of hydropower during sustained water shortages include:

upgrading operating practices; improving co-ordination and communication arrangements; and upgrading training and capacity-building programmes. These measures look to leverage process improvement and therefore have the potential to proceed relatively quickly. Upgrading the system operator's monitoring, analysis and real-time management tools and capabilities is a key proposed measure, which offers the potential to substantially reduce power system losses and to greatly improve management of sustained hydrological events. However, implementation of this measure is likely to rely on the deployment of significant technological and capital upgrades which could prove complex, time-consuming and expensive to develop and effectively implement in practice. These practical considerations are reflected in the longer period allocated in the roadmap for undertaking these activities.

Supply-side measures represent the backbone of the roadmap, providing the primary response and main resources for managing significant losses of hydropower during sustained water shortage events. However, analysis suggests that implementation of a sufficient contingency reserve would represent a considerable investment of capacity and financial resources. It would be unrealistic to expect this level of contingency reserve to be developed and deployed in the short term. Hence, the roadmap proposes a three-stage approach to its development.

The first stage would involve securing a working contingency reserve drawing from existing infrastructure. A potentially ideal source could be a portion of the underutilised generating capacity associated with the Bishkek Combined Heat and Power (CHP) plant. This plant represents a readily available source of thermal generation that is strategically located close to major loads, with the potential to be quickly deployed as an effective source of emergency power to offset the loss of hydroelectric power for the duration of a periodic seasonal hydrological shortage.

The second phase of the programme would seek to broaden and deepen the sources of supply secured for the contingency reserve. For instance, previously untapped sources of distributed generation could be considered, along with a limited volume of demand response from large loads. In addition, the potential to increase the contribution from the Bishkek CHP plant, or from the proposed second Bishkek CHP plant if it materialises, could be explored. The likely additional time required to undertake this phase is reflected in the time frames proposed in the roadmap. In the longer term, the third stage of the programme could seek to extend national and regional sources of supply. For instance, opportunities to broaden and deepen the provision of domestically sourced reserves could be explored, including demand response. Similarly, ongoing arrangements could be established to secure emergency operating reserves from regional power producers.

The demand-side measures proposed have the potential to improve existing rationing arrangements and to unlock a range of resources that can complement and reinforce traditional supply-side responses to address sustained power system security events. For instance, the communications strategy measure has the potential to help harness considerable voluntary power savings during a hydrological emergency event, while the contractual mechanisms measure potentially provide a practical means for securing contingency reserves from non-traditional sources, such as distributed generators.

Similarly, energy efficiency and power consumption substitution measures have considerable potential to deliver substantial power savings in the longer term. Accordingly, it is proposed that measures be developed and implemented to incrementally harness these power savings, initially focusing on improving building energy efficiency, and the deployment of more efficient space heating and appliances.

Overall, the roadmap provides an integrated and comprehensive approach for pursuing power system security in Kyrgyzstan. It incorporates a range of practical measures focusing on the key areas of power system management, production and consumption that will determine power system reliability and resilience during a sustained water shortage event. The roadmap also recognises the interrelated nature of the power system security challenges facing Kyrgyzstan during these periods, and will support the development of a mutually reinforcing set of policies and programmes that can address these matters in a practical, timely and cost-effective manner.

Introduction

The EU4Energy programme is a six-year initiative led and funded by the European Union. One of its key goals is to enable greater application of evidence-based energy policy and decision-making in participating countries in Eastern Europe and Central Asia.[1] The International Energy Agency (IEA), the Energy Community and the Energy Charter support the project, with the IEA taking lead responsibility for the policy development dimensions. As part of this programme, the IEA has prepared this high-level policy roadmap to help inform and guide policy practitioners as they seek to develop and implement policies to strengthen power system security in Kyrgyzstan, with a focus on improving power system reliability and resilience during periods of water shortage.

The analysis and proposals advanced in this document provide an integrated approach incorporating a suite of practical regulatory, supply-side and demand-side measures that reflect international experience and best practices. It avoids detailed prescription, recognising that Kyrgyz policy practitioners are better placed to draw on their local knowledge and experience to address practical details as they emerge. Accordingly, the roadmap's proposed measures and pathways are intended to inform and guide the development of effective policies and programmes to help strengthen power system reliability and resilience, especially during periods of water shortage.

This paper begins by discussing power system security concepts and principles, focusing on how power system security is managed during normal operating conditions and how this can change in hydro-dependent power systems during periods of sustained water shortage. A description of the policy context for power system security in Kyrgyzstan follows. It highlights the key challenges for strengthening power system security, and provides an overview of the policy, legal, regulatory and institutional arrangements governing power system security in Kyrgyzstan. Finally, an integrated high-level policy roadmap is presented, including proposed strategic goals and a range of practical policy measures to pursue power system security over the next decade.

[1] Countries participating in the EU4Energy programme are Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Tajikistan, Turkmenistan, Ukraine and Uzbekistan.

Power system security concepts and principles

Fundamentals of power system security

Electricity reliability is a very broad notion. At its simplest it can be defined as "keeping the lights on". However, this relatively simple definition provides little insight into its multifaceted nature. The concept of reliability needs to be unpacked if it is to be better understood and managed. Reliability in this context encompasses the ability of the value chain to deliver electricity to all connected users within acceptable standards and in the amounts desired. It possesses two fundamental dimensions.[2]

- **system security,** which refers to the capability of a power system using its existing resources to maintain reliable power supplies in the face of unexpected shocks and sudden disruptions in real time, such as the unanticipated loss of key generation or network components, loss of fuel, or rapid changes in demand
- **adequacy,** which refers to the capability of the power system using existing and new resources to meet changes in aggregate power requirements in the present and over time, through timely and flexible investment, operational and end-use responses.

These dimensions are interrelated. For instance, system security policies and practices help to establish the effective adequacy envelope of existing infrastructure in the present, while efficient, timely and well-located investment is needed to maintain power system adequacy and to provide the resources needed to maintain system security into the future. At the same time, access to reliable fuel supplies and efficient use of those supplies is required to ensure generation equipment operates reliably and predictably from a short-term power system security perspective, and to ensure that generation infrastructure is able to meet demand, and hence adequacy requirements, in the present and into the future.

Maintaining secure and stable power systems is fundamentally determined by the physical characteristics of electricity. In particular, unlimited cost-effective storage of electricity is not generally available, and electrical imbalances at any point can have immediate and severe repercussions for the quality and deliverability of electricity throughout a power system. As a result, supply and demand must be

[2] The definitions of system security and adequacy draw from those used by the North American Electric Reliability Corporation and the International Council on Large Electric Systems.

balanced in real time at every point across the whole power system to ensure reliable supply that meets defined voltage and frequency requirements. Balancing also needs to be done in near real time, where demand is largely inelastic[3] and production is subject to various technical constraints that limit its deployment, such as ramp-up and ramp-down rates.

Maintaining power system security is further complicated by the dynamic nature of power flows which follow the path of least resistance determined by the constantly changing balance of generation and load. Key to success is the simultaneous balancing of electricity flows to maintain frequency and voltage subject to system stability limits and the thermal operating limits of the network infrastructure. Together these technical requirements establish the envelope within which all power systems must be operated to maintain reliable and secure power supplies.

The unique properties of electricity combined with the technical requirements that have to be met to ensure stable and secure power flows make maintaining power system security a challenging balancing act that can be practically achieved only through centralised, or centrally co-ordinated, system operation. System operation is generally undertaken by transmission and distribution network owners or independent system operators, with a degree of co-ordination between them where integrated regional networks incorporate two or more control areas. System operators are also usually primarily responsible for executing emergency procedures to manage extreme events in a manner that minimises the impact on supply while protecting critical electricity infrastructure.

System operating practices

Operational experience has led to the development of various reliability standards and practices to ensure that power systems are operated in a stable and secure manner.

From a practical operational perspective, the most important of these reliability protocols is the ‘normal minus one’ (N-1) standard. A power system can be described as being N-1 secure when it is capable of maintaining normal operations[4] in the event of a single contingency event, such as the unplanned loss of a transmission line, generator or transformer. This standard has been adopted by system operators around the world to inform operational contingency planning, to guide management of system operation, and to guide emergency efforts to

[3] Electricity demand is typically fixed in the moment of dispatch, making it “inelastic” in this context.
[4] That is, reliably delivering electricity of a given frequency and voltage subject to meeting all other technical requirements.

return systems to a secure and stable operating condition within a reasonable time following a single contingency event, usually within 15 to 30 minutes.

Operating practices are designed to ensure that power systems are operated within the technical and operating standards, consistent with application of the N-1 protocol. They are typically built on an iterative process that involves contingency assessment and planning in the period leading up to dispatch, ongoing monitoring of system operation during each dispatch interval and intervention as required to address emergency events.

Initial contingency assessment is undertaken day-ahead and updated to incorporate new information that could significantly affect power flows, such as changes in the availability of generation or transmission lines and dispatch patterns. This information is fed into a computer simulation to identify potential points of congestion, and to determine the type, location and amount of technical reserves and other resources a system operator may need to prepare for credible N-1 contingencies.

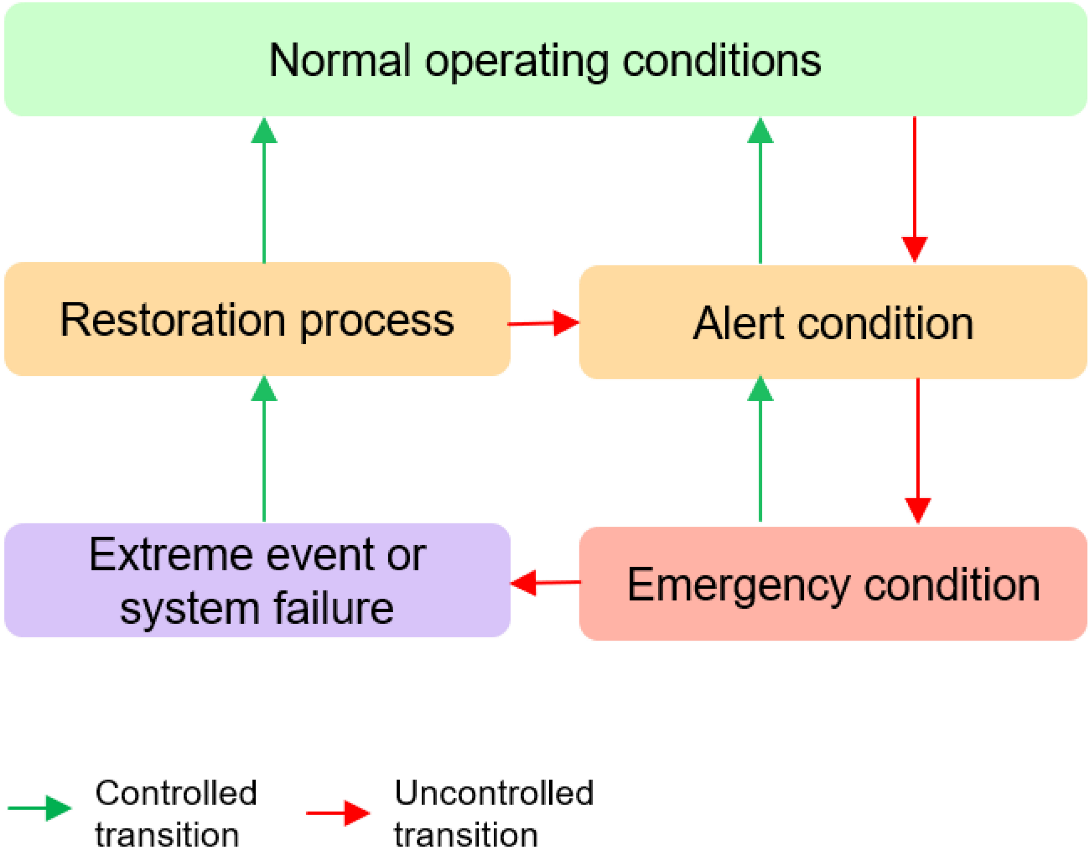
System operators monitor power systems in real time to ensure that secure operating conditions are maintained and so that they can respond in a timely and effective manner to emergency events. Operational management generally relies on sampling of real-time and near real-time information on power flows at strategic points in power systems using a supervisory control and data acquisition (SCADA) system.[5] Results are used to assess actual operational conditions against key technical constraints and fed into network simulations which are used to update contingency assessments.

When an emergency or N-1 contingency event occurs, system operators need to be able to intervene in a timely and effective manner to stabilise a power system and then return it to an N-1 secure state[6] within the maximum period permitted by the reliability standards. In the event of a blackout, system operators usually have restoration plans and procedures which are immediately activated to return a power system to a stable and secure operating condition as quickly as possible. The typical control framework adopted by system operators to manage emergency events and return systems to a secure operating condition is summarised in Figure 1.

[5] SCADA is a system of remote control and telemetry used to monitor and control the power system.

[6] An N-1 secure state is achieved when system conditions are such that a subsequent N-1 event could be absorbed without threatening stable system operation.

Figure 1 Typical control framework for managing power system security events



Source: Adapted from Dy Liacco, T. E. (1967), *The Adaptive Reliability Control System*; and IEA (2005a), *Learning from the Blackouts: Transmission System Security in Competitive Electricity Markets*.

System operating resources

System operators have traditionally used a combination of resources to manage power system security including various forms of technical or operating reserves and services, redispatch, and load shedding. The specific products, or ancillary services, available to help manage system security are usually defined in terms of their function and the time taken to deploy them. Key functions include frequency control, network control and provision for restoration of services following a blackout, usually referred to as black start services.

System operators would typically deploy operating reserves or employ redispatch before load shedding. Load shedding is usually treated as a last resort used to avoid catastrophic system failures. Products used to manage small routine imbalances and to react immediately to emergency events are deployed automatically in response to particular frequency, voltage or stability triggers, while other services tend to be deployed manually by system operators as required. The typical range of operating reserves available to most system operators is summarised in Box 1.

Box 1 Typical range of power system operating reserves

- **Frequency control regulation reserves**. These reserves, often delivered through automatic generation control, are used to manage small movements in frequency resulting from the constantly changing balance between generation and load on an integrated power system. They are automatically dispatched in real time.
- **Frequency control contingency reserves**. This is the "spinning" reserve, which is provided by power plants with turbines that are spinning in synchronisation with the common system frequency but are not generating power. Such capacity can provide an immediate and significant injection of power if required. Spinning reserves can typically be ramped up to full production in less than 10 minutes. Any conventional generator can provide this service.
- **Fast response active reserves**. These are essentially "non-spinning" reserves which can be deployed in a matter of minutes and be ramped up to full production within an hour. Spinning and non-spinning reserves are used to maintain services and to restore the balance between generation and load in the event of a sudden substantial generation or network outage. Generators with the technical capability to quickly ramp production up or down, such as hydro and gas-fired plants, are generally contracted to provide these services.
- **Slow response active reserves**. These reserves are typically employed in response to an unanticipated generation or network failure where sufficient advance notice is provided, or in response to a persistent emergency situation. Such reserves can usually be deployed within 4 to 8 hours. Most baseload generators are capable of providing these services.
- **Reactive power reserves**. These reserves provide reactive power to support voltage stability and power flows. Reactive power diminishes rapidly over relatively short distances and must be provided locally. Reactive power can be provided by any conventional generator and by purpose-specific equipment such as capacitors.

Source: IEA (2005a), *Learning from the Blackouts: Transmission System Security in Competitive Electricity Markets*.

System operators also procure black start services to facilitate system restoration following a blackout. These services are usually secured through bilateral contracts with generators, though system operators typically have the authority to requisition necessary services in an emergency.

Some system operators procure additional capacity reserves to help manage supply-demand balances and resource adequacy. This is a more common practice in energy-constrained power systems where the availability of generation is dependent on uncertain fuel supplies– for instance, power systems that are heavily reliant on hydroelectric production and hence are subject to periodic risk of electricity shortages due to drought.

In principle, demand response also has the potential to provide many of these services. System operators across IEA electricity systems are increasingly sourcing operating reserves from demand response providers. Large-scale loads provide the vast majority of these services at present. Considerable scope exists to expand the use of demand response to provide flexibility and system security services.

Managing power system security during sustained emergency events

Some power system security events are of a nature, scale and duration that are beyond the capability of system operators to manage using their normal emergency management practices and resources. Hydro-dependent power systems can be particularly susceptible to these kinds of events due to their exposure to periodic water shortages. Such events are likely to be a recurring challenge in these systems, with implications for the way they prepare for and manage these kinds of emergency events. Some recent examples are identified in Table 1.

Table 1 Examples of sustained emergency events in hydro-dependent power systems

Country	Year	Duration	Key demand-side measures deployed
California	2000-2001	9 months	Rationing, price incentives, public awareness/media campaigns, energy efficient appliance subsidies, upgraded energy efficiency standards.
Brazil	2001	10 months	Rationing, price incentives, public awareness/media campaigns, energy efficient appliance subsidies, fuel switching, public sector savings targets.
New Zealand	2001 and 2003	3 months (2001) 6 week (2003)	Price incentives, market-based responses, public awareness/media campaigns.
Scandinavia	2002-2003	4 months	Price incentives, market-based responses, fuel switching, public awareness/media campaigns.
Chile	2007-2008	Over 1 year	Fuel price stabilisation fund, electricity subsidies, reduced voltage, public awareness/media campaigns, daylight saving extension, price incentives, energy efficient appliance subsidies.

Sources: Adapted from IEA (2011a), *Saving Electricity in a Hurry: 2011 Update*; World Bank (2010a), *Managing an Electricity Shortfall: A Guide for Policymakers*; and IEA (2005b), *Saving Electricity in a Hurry*.

Understanding the nature and likely duration of a power disruption is critical for deciding how best to respond. The nature of power disruptions can be broadly divided into two dimensions:

- **Energy constrained**, which occur when a power system lacks the energy required to generate sufficient electricity to meet demand. Hydro-dependent power systems are particularly susceptible to this kind of disruption as a result of exposure to periodic periods of drought.
- **Capacity constrained**, which occur when power system infrastructure is insufficient to meet peak demand. These kinds of disruptions can occur as a result of rapid and unanticipated growth in demand, infrastructure failures, or a combination of both.

The expected duration of a disruption will also affect the types of measures that can be deployed. For instance, during a relatively short duration sustained emergency event, which may run for a period of days up to a few weeks, supply responses are generally limited to extracting more from the existing infrastructure, while demand restraint typically relies on rationing, voluntary savings and possibly scarcity pricing. More supply and demand options become available to address medium-duration events, which may run for up to six months, including some minor capital replacement (e.g. energy-efficient lighting), a wider range of pricing incentives and some limited fuel switching. While a wide range of supply and demand options become available to help tackle medium- and long-duration disruptions, including limited deployment of new infrastructure and the full range of pricing and regulatory incentives.[7]

An effective response will incorporate an appropriate mix of supply and demand restraint measures. The appropriate combination of measures will depend on the circumstances, which will reflect the nature and expected duration of the event. International experience suggests that responses will also reflect the feasibility of implementing particular measures and the legal, regulatory and market arrangements governing sector operations.

International experience also suggests some key principles for developing and implementing effective responses to sustained emergency events including:

- **Analyse the event**. Begin by developing a clear understanding of the causes, nature and likely duration of the event, including insight into how it is likely to affect generation capacity and response, network operation, and consumption patterns including potential for savings by customer class. Initial analysis provides a critical foundation for developing and implementing an effective response.

[7] See World Bank (2010a), p. 21, which proposes classifying the duration of sustained emergency events into very short duration (up to a few weeks); short duration (up to six months); medium duration (up to two years); and long duration (a period of two or more years).

- **Identify and assess potential responses**. Effective responses generally incorporate a few key supply, demand and regulatory initiatives, which can be implemented quickly and easily, have the potential to significantly alleviate the "crisis", are cost-effective and are likely to be socially acceptable. Develop an integrated programme incorporating the most practical, timely and cost-effective regulatory, supply-side and demand-side responses.
- **Adopt a timely and effective implementation strategy**. International experience shows that implementation has been best managed in jurisdictions that have prepared detailed emergency response plans in advance. Plans need to provide clarity around the roles and responsibilities of all the key stakeholders involved in implementation. They need to ensure that effective co-ordination and communication is maintained during the event to ensure an adaptable, timely and effective response. They also need to identify key information required to guide implementation and ensure that data collection and analysis capabilities are in place and ready to deploy when required.
- **Assess effectiveness and draw lessons**. Review the key outcomes and learnings from the event and the event response, and incorporate those lessons into preparations for the next event as part of an ongoing cycle of continual improvement and preparedness. Leading practice jurisdictions also seek to reinforce learning and preparedness through regular emergency response exercises.

Kyrgyzstan's power system security policy context

Kyrgyzstan's high dependence on hydropower exposes it to the risk of electricity shortages during periods of water scarcity. These risks are magnified by the growing fragility of the power system, which is in urgent need of generation and network investment to improve its operational reliability and to ensure that it has sufficient capacity to meet demand over time. The challenge is further amplified by rapidly growing electricity demand, fuelled by unsustainably low regulated electricity prices, which threatens to quickly outstrip domestic production capacity. Maintaining access to reliable electricity services is likely to become increasingly problematic in these circumstances, especially during periods of water shortage.

Key challenges for strengthening power system security

Kyrgyzstan's power sector is relatively small with total generating capacity of around 3.9 gigawatts, producing around 15.4 terawatt-hours (TWh) in 2020. Hydroelectric plants dominate the sector, representing 78% of total generating capacity. The remaining generating capacity is largely provided by thermal CHP plants serving the main population centres. The sector's heavy dependence on hydroelectric plants is reflected in domestic power production levels, with hydropower typically representing around 90% of Kyrgyzstan's annual power output during normal hydrological periods. Figure 2 shows current generating capacity and recent trends in power production in Kyrgyzstan.

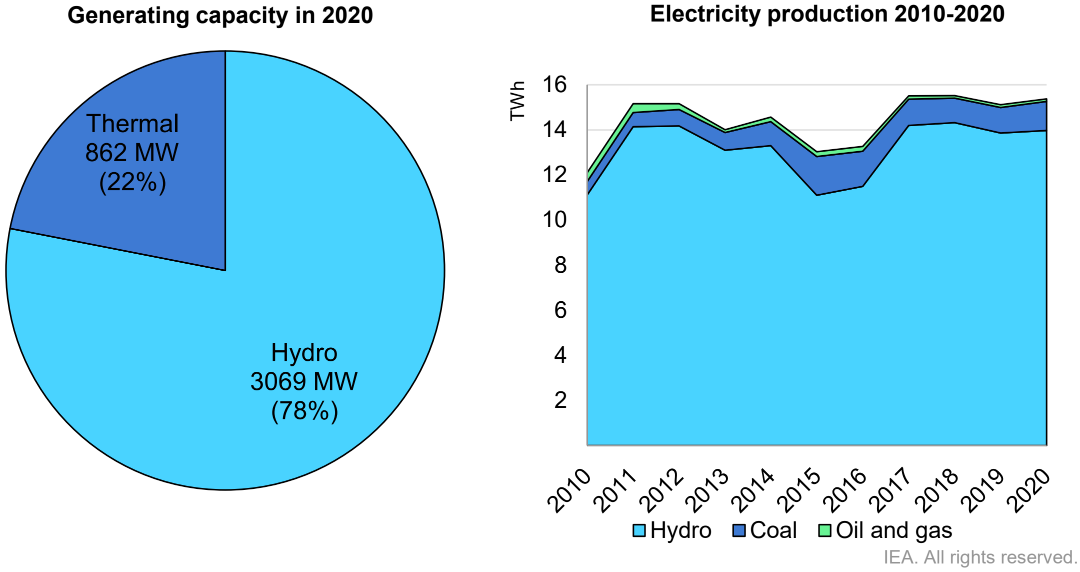
High dependence on hydropower raises concerns about maintaining the reliability of electricity supply and power system resilience during periods of water shortage. For instance, the power production trends presented in Figure 2 reflect the impact of water shortages on hydropower production during the last major water scarcity event in 2015 and 2016. During this period, average hydropower production fell to around 11 300 gigawatt-hours (GWh) per year, representing a fall of nearly 1 800 GWh (13.6%) compared with the ten-year average, with most of the production loss experienced during the winter months of 2015 and 2016.[8]

As a result, Kyrgyzstan experienced significant power shortfalls and rolling blackouts during the winter peak heating seasons in 2015 and 2016. Power

[8] See IEA (2022) for further details.

shortages also led to substantial increases in relatively expensive power imports and increasing power production from Bishkek's CHP plant during the winter period for the duration of this event, placing additional financial pressure on an already cash-strapped sector.[9]

Figure 2 Power generating capacity and production trends, Kyrgyzstan, 2010-2020



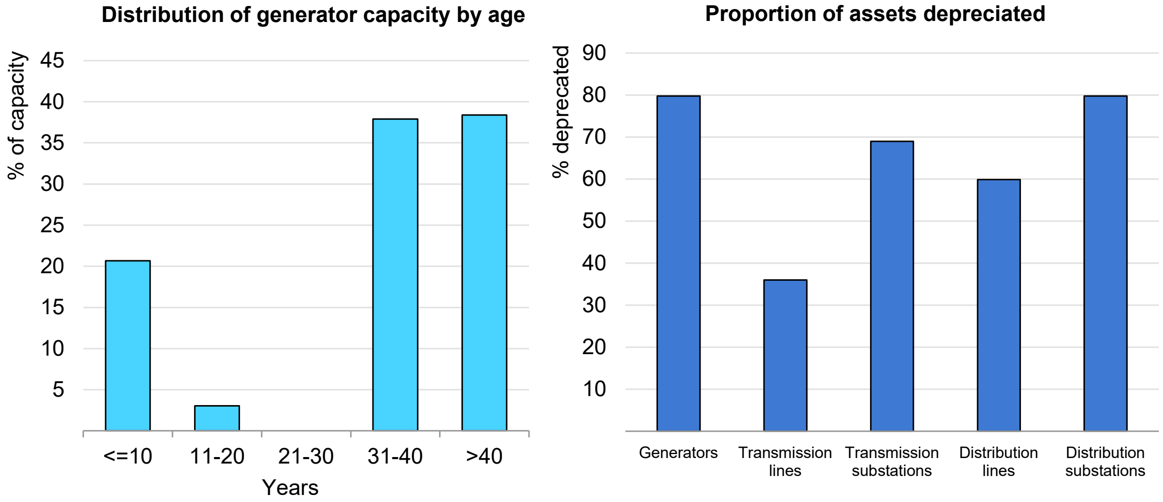
Notes: MW = megawatts. Thermal production shares for 2020 are estimates.

Sources: IEA (2022), *World Energy Statistics and Balances* (database); and State Committee for Industry, Energy and Subsoil Use (2020), Kyrgyzstan's Energy Sector 2020.

Reliability and resilience risks are magnified by the age and relative fragility of Kyrgyzstan's electricity infrastructure, as shown in Figure 3. The vast majority of the hydroelectric fleet is well over 30 years old, with a weighted average age of over 40 years and nearly 80% of its capital depreciated. Network infrastructure is also relatively old, with over one-third of all transmission lines depreciated and nearly 70% of the substations depreciated. Distribution assets are in similar condition, with depreciation of distribution lines and substations averaging around 60% and 80% respectively.[10]

[9] See IEA (2020), IMF (2019) and World Bank (2017) for further discussion. Similar outcomes were experienced during the preceding major water shortage event in 2008-2009. See World Bank (2014) for further details.
[10] See State Committee for Industry, Energy and Subsoil Use (2020) for details.

Figure 3 Power sector infrastructure status, Kyrgyzstan, 2020



Notes: Generation depreciation figures apply to Joint Stock Company (JSC) Power Plants generators only. Distribution depreciation figures represent an average across the four distribution companies.

Source: Adapted from State Committee for Industry, Energy and Subsoil Use (2020), Kyrgyzstan's Energy Sector 2020.

High levels of depreciation are typically reflected in higher operating costs, higher rates of unplanned outages and higher network losses. The government reported that over 4 600 supply disruptions were recorded in the distribution system in 2019.[11] The World Bank also notes evidence of unplanned infrastructure outages resulting from operating old and under-maintained assets, which served to exacerbate power system security challenges arising from water shortages experienced during the 2015 and 2016 winter peak seasons.[12] And the International Monetary Fund recently observed that old and unreliable power infrastructure had added considerable cost for private-sector power consumers in Kyrgyzstan, with economic losses representing around 4% of annual sales.[13]

Although the government reports significant reductions in distribution network losses over the last five years, they still remain relatively high by international standards with annual average losses of 12.3% recorded across the four distribution companies in 2019.[14] This figure is likely to significantly mask seasonal variability. For instance, on average over 75% of the losses in 2020 were recorded during the winter months,[15] with average distribution network losses around 14.4% over this period. Winter network losses across the four distribution businesses

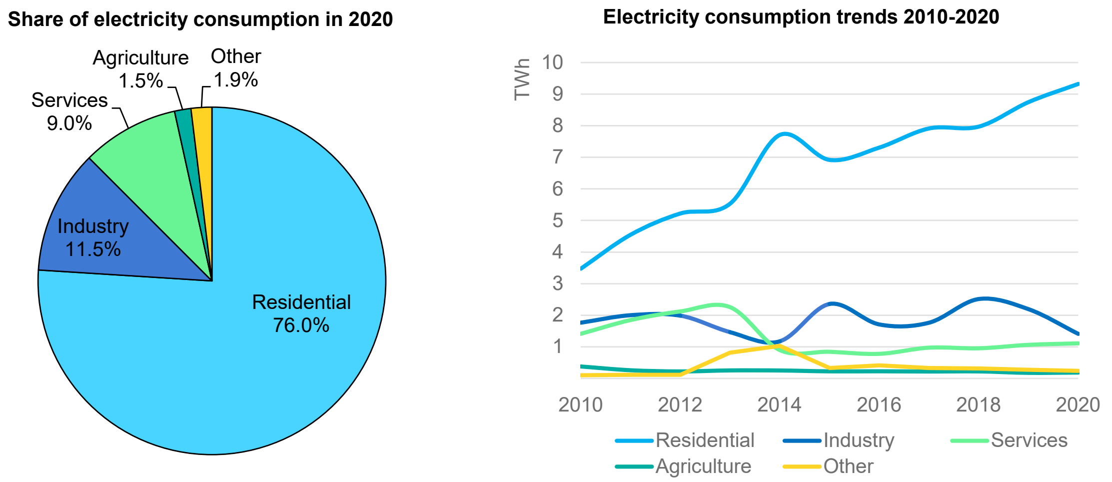
[11] The annual number of disruptions recorded has been steadily decreasing over the last six years, with the 2019 result around half of the number of supply disruptions recorded in 2014. See State Committee for Industry, Energy and Subsoil Use (2020) for further details.
[12] See World Bank (2017), pp. 25-26 for details.
[13] See IMF (2019), p. 7 for further discussion.
[14] See State Committee for Industry, Energy and Subsoil Use (2020), which reports average distribution network losses of around 12.3% in 2019, down from around 16.5% in 2014.
[15] In this context, "winter" months are defined to include the six-month period from October to March inclusive.

ranged from 12.8% to 17.0% in 2020.[16] These differences are likely to be largely explained by increasing rates of economic loss associated with the winter peak heating season rather than technical losses. However, this seasonal variability suggests that losses may be more significant from an electricity security perspective during winter periods when they are more likely to coincide with water shortages that jeopardise hydropower production.

The combination of hydro dependence and ageing electricity infrastructure greatly increases Kyrgyzstan's exposure to potential power supply shortages and power system failures, especially when the power system is under additional stress during periods of water scarcity.

These risks are compounded by rapidly increasing demand for electricity, especially in the residential sector, which is a key driver of growing power demand during the peak winter season. Figure 4 shows that in 2020, the residential sector dominated power use, accounting for 76% of total final electricity consumption. The industrial sector was the next-largest electricity consumer in 2019, accounting for around 12% of total final electricity consumption. In 2020, around two-thirds of annual electricity consumption occurred during the winter period for all consumer classes except the agricultural sector, reflecting growing use of electricity for space heating, especially among residential consumers.[17]

Figure 4 Electricity consumption shares and trends by customer class, Kyrgyzstan, 2010-2020



Note: *Other* category includes energy sector, transport and unspecified consumption.

Source: IEA (2022), *World Energy Statistics and Balances* (database).

[16] See JSC National Settlement Center (2021) for further details.

[17] Analysis drawing this conclusion has been presented in several recent publications including: World Bank (2020), pp. 7-11; IMF (2019), p. 7; ECS (2018); World Bank (2017), pp. 26-28; and World Bank (2014).

Total final consumption of electricity grew by 72% between 2010 and 2020, to around 12 260 GWh. Figure 4 confirms that rapid growth in residential electricity consumption was the primary contributor to growing power consumption over the period. Residential electricity consumption grew by nearly 170% between 2010 and 2020, to 9 320 GWh. By contrast, trends in electricity demand among the other consuming sectors were variable and subdued, exhibiting little or no growth over the period.

These trends have implications for pursuing power sector reliability and resilience. Residential power consumption is the key driver of growing power demand during the peak winter season, which is also the most likely period for water shortages to jeopardise the reliability of hydropower production. This suggests some potential priorities for power system security policies, in particular, for demand-side management programmes seeking to reduce power use during future power shortages.

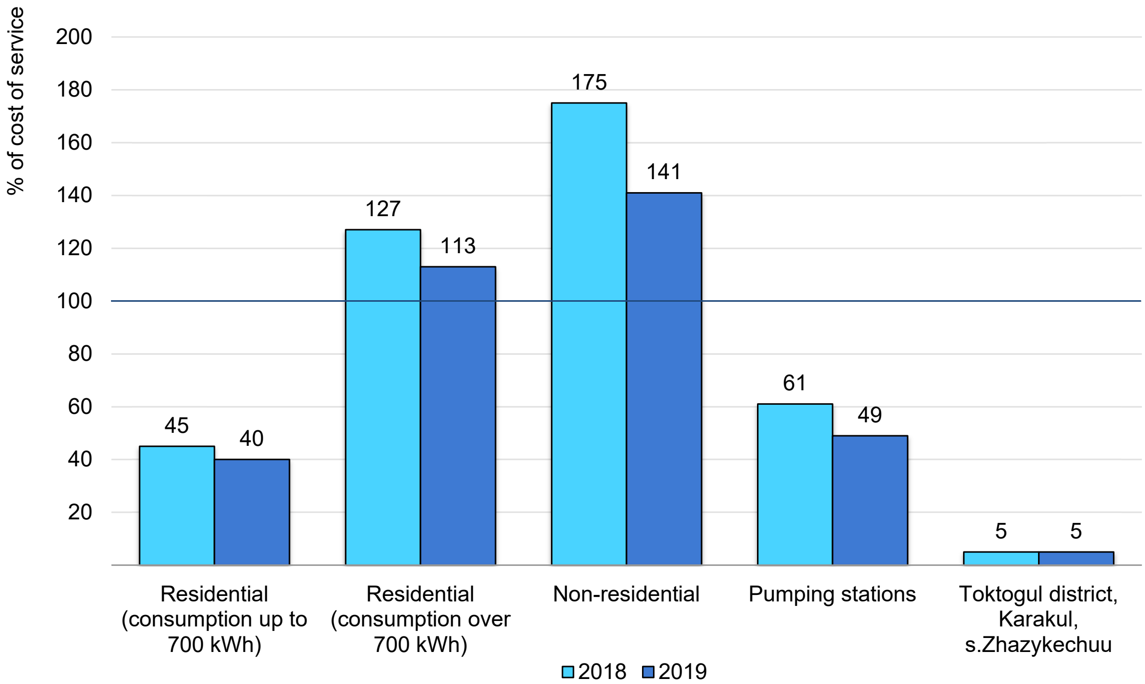
Rapid growth in residential consumption has been driven by regulated electricity prices which have been set well below the cost of production. The impact of regulated price movements on consumption can be seen in Figure 4, which reflects a significant positive correlation between changes in consumption patterns and changes in regulated tariffs over the period.[18] This suggests that Kyrgyz electricity demand is responsive to changes in regulated tariffs. Consumption trends also suggest that the ongoing process of increasing electricity tariffs towards cost-reflective levels would help to moderate the rate of growth in electricity consumption while encouraging greater energy efficiency and ongoing energy savings. This suggests that expediting the tariff reform programme could make a significant positive contribution towards improving power sector reliability and resilience in the present and into the future.

However, electricity prices for the majority of consumption are currently set at levels well below the cost of production, as shown in Figure 5. In particular, residential tariffs for the "up to 700 kWh" consumption block have remained unchanged since 2015, despite several policy announcements incorporating tariff increases for this consumption block over recent years.[19] The International Monetary Fund has concluded that the current subsidy regime is highly inefficient and poorly targeted, with nearly half of the electricity, district heating and hot

[18] For example, the changes in consumption patterns observed in 2014-2015 reflect the initial implementation of the Medium-Term Tariff Policy 2014-2017, which included the introduction of a highly concessional 700 kilowatt-hour (kWh) tariff block for residential customers and significant increases in tariffs for non-residential and high-volume residential consumers. See Government of the Kyrgyz Republic (2014) for further details.
[19] Regulated tariffs applying to the bulk of load have not increased since 2015, despite several announced policies calling for tariff increases over the period. See Government of the Kyrgyz Republic (2021a), Government of the Kyrgyz Republic (2021b), Government of the Kyrgyz Republic (2020) and Government of the Kyrgyz Republic (2014) for further details.

water subsidies going to the richest 30% of households, while the bottom 30% receive barely 20% of the subsidies.[20]

Figure 5 Electricity tariffs as a percentage of the cost of service, Kyrgyzstan, 2018-2019



Note: Further information about the World Bank's cost of service modelling framework is provided in World Bank (2017), Appendix D, pp. 59-61.

Source: World Bank (2021), The state of the Kyrgyz energy sector.

Residential consumption represents approximately 70% of the electricity load, and the majority of that consumption falls within the "up to 700 kWh" pricing block, which is among the most heavily subsided consumption categories.[21] Although commercial and industrial consumers and large-volume residential consumers are paying well over a cost-reflective price for their consumption, the total revenue generated through this cross-subsidy is insufficient to offset the total revenue lost through subsidising the "up to 700 kWh" pricing block.[22]

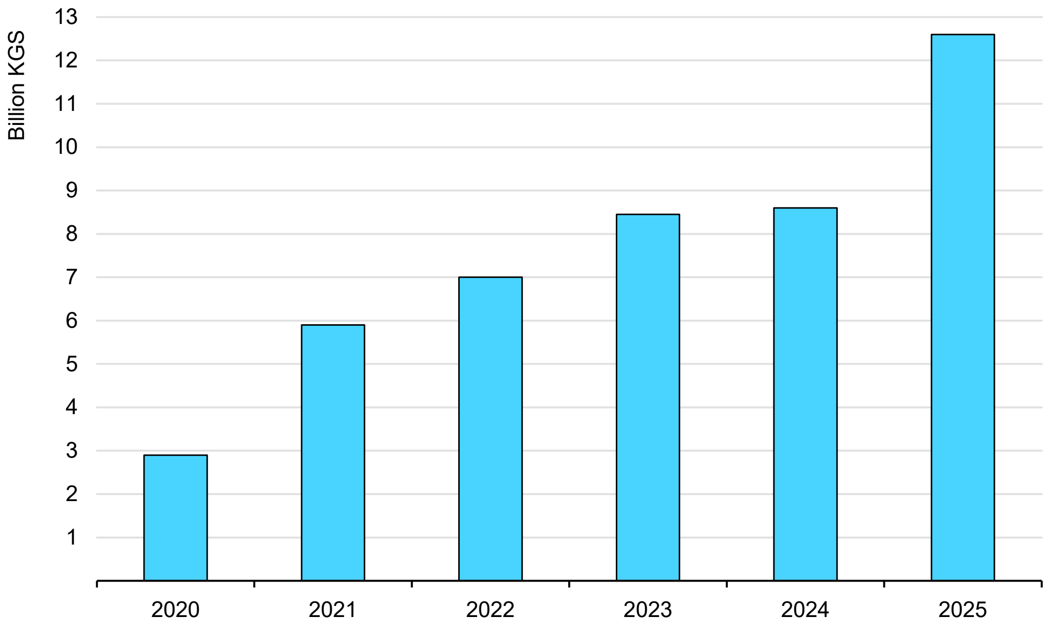
Accordingly, the power sector is operating in a financially unsustainable manner that is unable to generate sufficient cash flow to fund necessary maintenance and refurbishment, or to finance new investment in a timely and efficient manner. This has been reflected in dangerously low levels of maintenance and investment, and increasing reliance on foreign grants and project funding from international financial institutions to undertake critical refurbishment and sector modernisation

[20] See IMF (2019), p. 21 for further discussion.
[21] The World Bank estimates that 81% of residential consumption is subsidised through the "up to 700 kWh" tariff block. See World Bank (2017), p. 39, for further discussion.
[22] See World Bank (2017), p. 34, for further discussion.

over the last two decades. As a result, the nature, scope and pace of electricity sector modernisation have been constrained, further eroding power sector reliability and resilience over time.

Financial unsustainability is also reflected in ballooning sector deficits, as highlighted in Figure 6, which shows the results of modelling undertaken by the World Bank.

Figure 6 Electricity sector deficit forecast, Kyrgyzstan, 2020-2025



Notes: KGS = Kyrgyzstani som. As at 30 June 2021, 1.0 USD = 84.70 KGS; and 1.0 Euro = 100.38 KGS.

Source: Adapted from World Bank (2021), The state of the Kyrgyz energy sector.

World Bank analysis indicates that the electricity sector deficit is likely to increase from around KGS 3 billion (Kyrgyzstani soms) in 2020 to more than KGS 12 billion by 2025 (approximately USD 150 million), assuming no change to current tariffs and no new capital expenditure. Given government ownership of the sector and its level of financial distress, it is likely that any additional debt ultimately will be transferred to the budget.

However, public investment in the power sector is already considerable. International Monetary Fund analysis suggests that electricity sector debt had reached almost 20% of GDP and around 32% of overall public debt in 2016. Loan repayments are projected to continue increasing and to exceed 1% of GDP on average between 2019 and 2023.[23] Similarly, the latest World Bank analysis suggests that the energy sector's cumulative debt has reached KGS 103.3 billion,

[23] See IMF (2019), p. 21, for details.

and is likely to remain steady at around 18% of GDP. At the same time, the loan repayment schedule is forecast to quadruple between 2018 and 2025 before plateauing, assuming no additional debt is incurred.[24] The government's potential to further invest in the sector is likely to be limited by financial constraints and competing policy priorities, placing a substantial financial constraint on public funding of power sector debt and modernisation going forward.

Increasing residential tariffs to cost-reflective levels offers the only viable option for permanently addressing the sector's cash flow crisis. In 2015, electricity consumption represented between 2.3% and 2.6% of total household expenditure, which was one of the lowest levels recorded in the region.[25] In principle, this suggests that most residential consumers may have the financial capacity to pay more cost-reflective tariffs, and that the transition towards cost-reflective tariffs could proceed relatively quickly. However, in practice, increasing electricity prices to cost-reflective levels is unlikely to be feasible in the short term, reflecting limited consumer willingness to pay and likely high community resistance.[26] Residential tariff reform has become a highly sensitive political issue, which has resulted in slow and limited action over a long period. Government and regulatory reluctance to address this challenge is reflected in the current Medium-Term Tariff Policy, which envisages no change to the residential "up to 700 kWh" pricing block before 2023.[27]

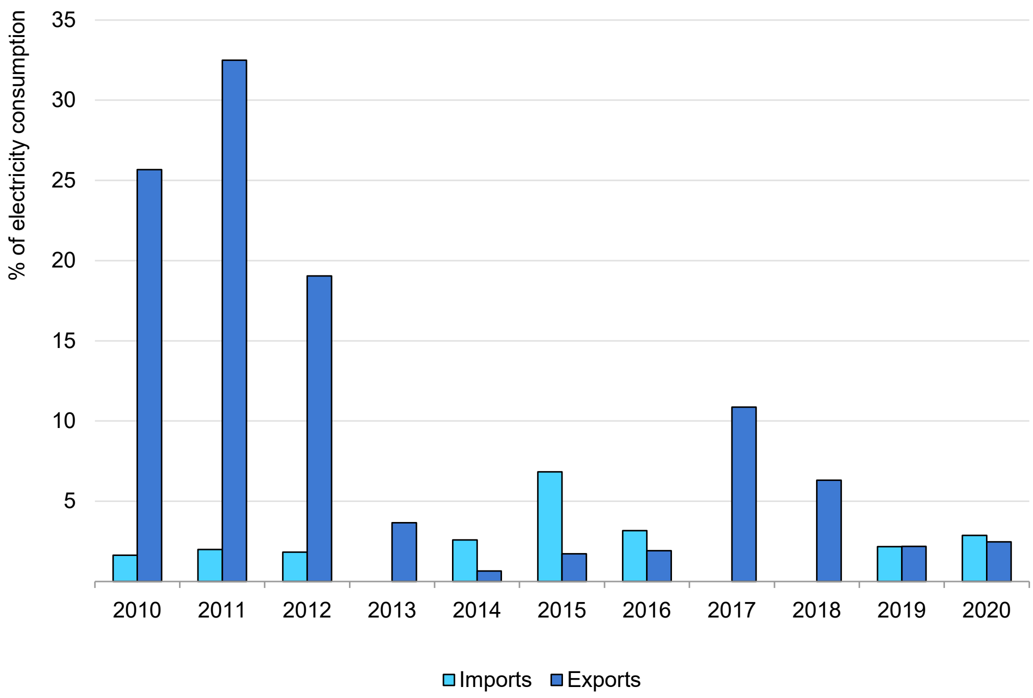
Increasing power exchanges through the Central Asian Power System (CAPS) offer considerable potential to help alleviate Kyrgyzstan's growing power system reliability, resilience and imbalance issues in a timely, proven and cost-effective manner. In particular, greater regional integration could expand the reserves available to help improve Kyrgyzstan's power system reliability and resilience during periods of water shortage, especially those occurring during winter peak periods, while also providing opportunities for regional electricity exchanges to help address its deteriorating supply-demand balance over time. CAPS was originally designed to operate in an integrated manner across the region, with a view to maximising the potential benefits from an economic and electric reliability perspective for all regional participants.[28]

However, integrated operation of CAPS has greatly decreased since the member jurisdictions gained their independence and began pursuing electricity security objectives based on greater "self-sufficiency" and "self-reliance", reflecting

[24] See World Bank (2021) for details.
[25] See World Bank (2017), pp. 37-38, for further discussion.
[26] See World Bank (2017), p. 39, for further discussion.
[27] See Government of the Kyrgyz Republic (2021a) for details. In addition, under a Presidential Decree of 6 December 2021, electricity tariffs for low-income families with children under 16 years receiving the state allowance decreased from 0.77 KGS to 0.50 KGS for consumption below 700 kWh per month, effective from 1 January 2022.
[28] See World Bank (2010b), pp. 10-25, for a good overview of CAPS, and the original principles governing its operation and development.

growing regional uncertainty and mistrust, and a range of disparate policy objectives. This fundamental shift is reflected in changing patterns of electricity trade, as shown in Figure 7.

Figure 7 Electricity trade trends, Kyrgyzstan, 2010-2020



Source: IEA (2022), *World Energy Statistics and Balances* (database).

Kyrgyz electricity exports declined substantially over the period, falling from an average of around 25% of total final electricity consumption between 2010 and 2012 to an average of less than 4% of total final electricity consumption between 2014 and 2020. Falling exports over the period have substantially reduced cash flows into the power sector, which has exacerbated the financial instability jeopardising efficient and reliable sector operation and development. At the same time, electricity imports remained low, averaging around 2% of total final electricity consumption over the period. These trends reflect increasing reliance on national operation and management of power systems and electricity supply.

Greater reliance on national operation has exposed inherent weaknesses within the Kyrgyz power system that have the potential to magnify power system security and reliability challenges, especially during periods of water scarcity, while also greatly increasing related management costs. Recent efforts to rebuild regional electricity trade have been led by a number of major infrastructure and technical projects being undertaken with the support of international partners.[29] However, various political, economic and infrastructure constraints across the region are likely to limit and slow the realisation of these objectives in practice.

The combination of these factors places Kyrgyzstan's electricity sector in a precarious position. As a result, Kyrgyzstan's power services are likely to become less and less reliable and resilient over time, jeopardising power system security. At the same time, if power consumption continues to grow at current rates without corresponding sector investment, it is increasingly likely that the national electricity system will no longer be able to meet demand by the end of the decade at the latest, raising fundamental system adequacy concerns which are likely to worsen considerably over the medium to long term.[30]

Policies and institutions influencing power system security

The government of the Kyrgyz Republic recognises these challenges and has adopted a strategic policy framework reflecting its ongoing commitment to strengthen power system reliability and resilience, consistent with achieving its wider energy security and self-sufficiency objectives.[31] This commitment is reflected in the principal strategic policy objectives guiding the development of the electricity sector, which include:

- Developing generation and network infrastructure in a manner that will ensure energy security and the self-sufficiency of the power sector.
- Delivering reliable supply of electricity and heat energy for domestic consumers.
- Improving the efficiency of electricity and heat generation, transmission and distribution through modernisation and the deployment of new technologies.

A range of policies have been implemented to help realise these policy goals. Principal among them have been several initiatives to rehabilitate and modernise generation facilities. These projects have typically sought to increase generating capacity, improve technical and operating efficiency, and strengthen electricity security. Table 2 identifies some key examples.

Other potential generation investments are also being proposed including several major renewable generation projects and the possibility of nuclear generation in

[29] Several international financial institutions and development agencies are actively supporting countries in the region to improve the reliability of their power supply through infrastructure expansion, upgrade and modernisation, and by encouraging stronger regional integration of national power systems. Leading examples include the Central Asia South Asia Electricity Transmission and Trade project (CASA-1000), and the Central Asia Regional Electricity Market project (CAREM).
[30] See IMF (2019), p. 18, for further discussion.
[31] See Government of the Kyrgyz Republic (2008) and Government of the Kyrgyz Republic (2012) for details.

the longer term.[32] Investments in new generating capacity will be needed to address looming electricity supply shortages. However, careful planning and integration of new capacity additions will be required to maximise their contribution to electricity supply while avoiding any unintended power system security outcomes that have the potential to worsen overall reliability of supply. In particular, given the relatively small size of the Kyrgyz power system, the age and fragility of power system infrastructure and the system operator's limited capacity to manage real-time intermittence, care will be needed to avoid unduly large increments of variable renewable generating capacity, which could greatly increase the risk of operational instability resulting in power system failure. Investment will also be needed in network infrastructure and power system management capability to help improve the flexibility and resilience of the power system as the volume of variable renewable generation increases.

Several projects have been undertaken to reinforce and augment transmission network infrastructure, including regional transmission interconnectors. Crucial among these is the 500 kilovolt (kV) Datka-Kemin transmission line, which was commissioned in 2015 and provides the first substantial transmission path located wholly within Kyrgyzstan's borders connecting the main generation centres in the south with the main consumption centres in the north. Other network projects with the potential to significantly improve power system security include:[33]

- Commissioning of an automated metering and data acquisition (AMDA) system linking 190 substations and generation facilities. The AMDA system aims to help reduce scope for economic losses (theft) and improve monitoring of interregional power flows, bringing them up to the CAPS metering standard.
- Rehabilitation of over 100 selected substations to improve the reliability of the Kyrgyz power system by replacing circuit-breakers and instrument transformers that have reached the end of their economic lives, are technologically obsolete or do not meet regional standards for accuracy.
- Installation of a communications and SCADA system for the northern transmission network loop linking seven key substations and the control centre via optical fibre cable. The SCADA system will enable the system operator to make more efficient dispatch decisions based on real-time data. It will also reduce technical losses through avoiding overloading and enable faster detection and restoration of faults. The system has the potential to improve the overall efficiency and reliability of the Kyrgyz power system and CAPS.

[32] See Government of the Kyrgyz Republic (2022), KyrgyzKabar News Agency (2022a), KyrgyzKabar News Agency (2022b), KyrgyzKabar News Agency (2022c), Kaktus Media (2022a) and Kaktus Media (2022b) for further information about the latest generation project proposals.
[33] See ADB (2021) and ADB (2020) for further details.

Table 2 Major current and recent generation investment projects in Kyrgyzstan

Project	Description	Investment and scheduled completion	Key partners
Toktogul Hydropower Plant (HPP)	The project includes: replacement of electro-mechanical equipment; complete replacement of all 4 hydro turbines; and the reconstruction of water gates and hydro-mechanical equipment. Capacity is expected to increase from 1200 MW to 1440 MW (an increase of 240 MW; nearly 20%).	USD 385 m (approx.), scheduled for completion in 2024.	• Asian Development Bank • Eurasian Development Bank • Eurasian Fund for Stabilization and Development • OJSC "Electric Power Plants of Kyrgyzstan"
Kambarata 2 HPP	The project includes: construction of a second hydro unit with installed capacity of 120 MW; and construction of 110 kV and 500 kV connections to the transmission network. Installed capacity will double to 240 MW; however productive capacity could effectively increase to up to 270 MW as a result of releasing previously 'locked' capacity.	USD 110 m (approx.), scheduled for completion in 2024.	• Eurasian Development Bank • Eurasian Fund for Stabilization and Development • OJSC "Electric Power Plants of Kyrgyzstan"
Uch-Kurgan HPP	The Uch-Kurgan HPP Modernization Project includes replacement of four power units, which will increase of installed capacity from 180 MW to 216 MW (an increase of 36 MW; 20%).	USD 145 m (approx.), scheduled for completion in 2025.	• Eurasian Development Bank • Eurasian Fund for Stabilization and Development • OJSC "Electric Power Plants of Kyrgyzstan"
At-Bashy HPP	Refurbishment of At-Bashy HPP is expected to increase installed capacity from 40 MW to between 42 MW and 44 MW (an increase of 2-4 MW; 5-10%). Power production is estimated at around 160 GWh per year.	USD 22.2 m (approx.), scheduled for completion in 2021.	• Swiss government • OJSC "Electric Power Plants of Kyrgyzstan"
Bishkek Combined Heat and Power (CHP) Plant	The project included the construction of 2 new power units and related infrastructure capable of generating up to 300 MW and up to 300 Gcal of heat. Modernization has increased installed capacity from around 660 MW to 812 MW (an increase of 252 MW; delivering an estimated increase in generating capacity of around 20% and an increase in heat capacity of around 30%). It also allowed fuel switching to locally produced coal.	USD 386 m, completed in 2017.	• Export-Import Bank of China • OJSC "Electric Power Plants of Kyrgyzstan"

Sources: State Committee for Industry, Energy and Subsoil Use (2020); IEA (2020), *Kyrgyzstan Energy Profile*; UNECE (2018), The Kyrgyz Republic: Energy Sector Review in 2018; World Bank (2017), *Analysis of the Kyrgyz Republic's Energy Sector*; and various international financial institutions and donor agencies.

In addition, several other projects are proceeding to refurbish and modernise key distribution network infrastructure to help improve reliability and decrease technical and commercial losses. These projects include the reconstruction of electrical networks and installation of advanced metering systems in the Jalal-Abad, Osh and Batken regions in the south of Kyrgyzstan, and in the Tup and Jeti-Oghuz regions in the east of Kyrgyzstan. Other elements of these projects are seeking to introduce corporate governance reforms and process improvements consistent with best practice established by the International Organization for Standardization.[34]

Beyond these projects, 455 kilometres (km) of new 500 kV transmission line is planned for Kyrgyzstan under CASA-1000, which has the potential to strengthen regional interconnection and overall power system reliability from 2023.[35] Several related projects are proceeding with the support of international partners.[36]

Policies to improve energy efficiency and promote energy saving also have considerable potential to strengthen power system reliability and resilience by helping to moderate the rapid growth in electricity consumption. The government has estimated potential electricity savings associated with more efficient energy use at between 20% and 25% of total electricity consumption, while potential energy savings associated with more efficient space heating have been estimated at around 15% of heat consumption.[37]

Kyrgyzstan has enacted a range of laws in relation to energy efficiency and energy conservation. The primary legislation governing energy efficiency is contained in the Law on Energy Conservation, with more detailed provisions in relation to building energy efficiency provided in the Law on Energy Conservation and Energy Efficiency.[38] Implementation is governed by the State Programme on Energy Saving and Energy Efficiency Policy Planning for 2015-2017, which incorporates a series of targets including an annual decrease in energy intensity of 30% per annum and a decrease in electricity consumption of 5% per year between 2015 and 2025. It is envisaged that much of the energy saving will be delivered through incentives targeting the development and use of energy-efficient appliances,

[34] These projects are proceeding with the support of the European Bank for Reconstruction and Development and the European Union. See EBRD (2021a), EBRD (2021b) and UNECE (2018) for details.
[35] The CASA-1000 project involves the construction of a 1 200 km high-voltage transmission line to facilitate seasonal trade among Kyrgyzstan, Tajikistan, Afghanistan and Pakistan. The project was approved in 2012 by all participating countries. Construction commenced in 2019. The completion of the Kyrgyz component is planned for 2023. See IEA (2020) for further details.
[36] For instance, the United States Agency for International Development (USAID) has committed USD 400 000 to provide secretariat support for the CASA-1000 project and to provide technical assistance, advisory services and capacity building to multiple stakeholders in Kyrgyzstan in the context of promoting the development of CAREM. See USAID (2021a) and USAID (2021b) for further details.
[37] See Government of the Kyrgyz Republic (2015) for details.
[38] See Government of the Kyrgyz Republic (1998) and Government of the Kyrgyz Republic (2011) for details.

technologies and materials for the production, transmission and consumption of electricity and natural gas by 2020.[39]

Many of the energy efficiency laws and policies enacted to date are comparable with international best practice, especially those relating to buildings. However, few have been fully or effectively implemented, reflecting relatively weak monitoring and enforcement. As a result, considerable scope remains to increase energy efficiency, especially in the residential and industrial sectors. In addition, there appear to be significant gaps in the policy framework including in relation to establishing minimum energy performance standards, energy labelling of appliances, public procurement and energy audits. A recent peer review of Kyrgyzstan's energy efficiency policies concluded that considerable scope exists to strengthen and expand the coverage of energy efficiency policies, and to improve monitoring and enforcement.[40]

Policies in relation to electricity pricing have the potential to substantially strengthen power system reliability and resilience in Kyrgyzstan. Ultimately, cost-reflective electricity pricing is needed to deliver the revenue required to repay debt and to fund investment and modernisation. At the same time, cost-reflective pricing is needed to create robust incentives for more timely and efficient investment, operation and consumption decisions in the power sector. Realising this potential would provide a strong foundation for improving electricity security in the present and beyond.

The most recent step in the electricity and heating price reform programme was taken in September 2021, when the government approved the medium-term tariff policies for electricity, heating and hot water for 2021-2025, with the objective of making electricity, heating and hot water tariffs more cost-reflective while providing affordable energy for the most vulnerable customers.[41] However, the critical challenge of lifting residential electricity tariffs towards cost-reflective levels remains unresolved, with regulated tariffs unchanged since 2015.[42] As a result, it appears that electricity pricing policy will continue to constrain efficient and timely power sector development, with the potential to increasingly jeopardise power system adequacy, reliability and resilience into the future.

Institutions and stakeholders

In Kyrgyzstan, institutional responsibility for the electricity sector is distributed among several bodies. The key institutions with roles and responsibilities that

[39] See Government of the Kyrgyz Republic (2015) for further details regarding the targets and policy measures.
[40] See ECS (2018) for further details regarding Kyrgyzstan's energy efficiency policies and practices.
[41] See Government of the Kyrgyz Republic (2021a) and Government of the Kyrgyz Republic (2021b) for further details.
[42] See World Bank (2021) and IMF (2019) for further discussion of recent tariff reform developments and related issues.

substantially determine electricity security outcomes from a policy, regulatory, investment, consumption and system operations perspective include:[43]

- The **Ministry of Energy,** which is responsible for formulating strategic energy sector policy. Its functions include: co-ordinating energy sector planning and development strategies; creating conditions for the development of renewable energy sources; undertaking monitoring and forecasting of electricity supply and demand balances; and the development of policy measures and regulations to achieve energy sector goals, including incentives for energy efficiency and measures for the modernisation and reconstruction of power plants, substations, power lines and other electric power facilities.
- The **Department for the Regulation of the Fuel and Power Complex** within the Ministry of Energy, which is responsible for energy sector regulation. Its functions include: developing tariff methodologies and setting tariffs for electricity, heating and natural gas; licensing for energy sector activities; developing and supervising the performance reporting and monitoring framework for energy sector companies; and undertaking dispute resolution and awareness-raising activities.
- The **Technical Safety Service** within the Ministry of Energy, which is responsible for supervising and regulating compliance with safety requirements, land legislation requirements, and technical requirements in the energy sector.
- **JSC Kyrgyz Electricity Settlement Center** which was established in August 2015 with the objective of streamlining transactions, improving efficiency and increasing overall financial transparency in the electricity sector. It uses a centralised information and analytical system for collecting, monitoring, analysing and validating data on electricity flows and losses; compiling electricity balances; and calculating financial settlements between electricity sector participants.
- **JSC National Energy Holding,** which was established in 2016 to support efforts to improve corporate governance and managerial efficiency within the main state-owned generation and network enterprises. It exercises the government's controlling stake in key enterprises operating in the electricity sector including JSC Electric Power Plants, JSC Chakan HPP; JSC National Electrical Grid of Kyrgyzstan, the four distribution companies and Bishkek's district heating service provider JSC BishkekTeploset. It provides direction through its participation on the boards of each of these enterprises, through which it is able to influence key strategic activities and decision-making including appointment of executive board members, approval of company strategies, setting business targets and key performance indicators, performance monitoring, and internal auditing.
- **JSC National Electrical Grid of Kyrgyzstan,** which is responsible for all aspects of national power system operation including management of generation dispatch and power flows on the main transmission system to ensure reliable, secure and stable delivery of electricity services to all consumers. It also shares responsibility for co-ordinating the management of power system security with other national

[43] See IEA (2020), p. 10; UNECE (2018), pp. 18-20; and World Bank (2017), Appendix A, for further details.

system operators within the CAPS region. Accordingly, it has a pivotal role in maintaining electricity reliability and ensuring power system security within Kyrgyzstan.

Recent changes to institutional arrangements, in particular the creation of JSC National Energy Holding, have served to consolidate public management and control of the Kyrgyz power sector. This could be viewed as a retrograde step from the perspective of establishing a more liberalised power sector characterised by greater efficiency, innovation, competition and transparency. Greater consolidation may also increase the challenge facing regulators, particularly in relation to performance monitoring and implementing best practice forms of incentive regulation which could be deployed, among other things, to help strengthen electricity security outcomes. Access to accurate and timely information will be crucial for addressing these issues. JSC Kyrgyz Electricity Settlement Center is likely to have a key role to play in helping to address the information asymmetries facing regulators and policy makers in this context.

Developing a power system security policy roadmap for Kyrgyzstan

Policy responses to date have focused on addressing the longer-term adequacy dimensions of the power system reliability and resilience challenge. However, relatively little attention has been given to addressing the more immediate power system security challenges facing the Kyrgyz power system.

Opportunities exist to implement a range of policies that could help to strengthen power system security in the shorter term, especially during periods of water shortage when power system reliability and resilience is likely to be under greatest stress. A comprehensive and integrated policy approach will be needed to help address this challenge in a timely, efficient and cost-effective manner. The following section outlines a way forward, built on a clear strategic policy goal and a set of mutually reinforcing policy measures that could be deployed to help strengthen power system security in Kyrgyzstan now and over the next decade.

Strategic goal

All effective policy roadmaps are built on clear strategic goals that provide the foundation for directing and driving the development and implementation of related policy measures. Strategic goals need to be simple statements of high-level policy intent. They also need to be realistic and feasible to implement, reflecting the practical circumstances governing policy development and implementation in relation to power system security.

The nature and scope of the reliability challenges facing the Kyrgyz power sector combined with the practical imperative to quickly improve the operational reliability and resilience of the power system during periods of water scarcity suggest the following key strategic goal for the roadmap.

Box 2 Proposed strategic goal for the roadmap

- To help improve power sector reliability and resilience in Kyrgyzstan in the short term by quickly strengthening power system security, especially during periods of water scarcity.

The proposed goal focuses on strengthening the operational reliability and resilience of the Kyrgyz power sector in the short term. It focuses on a practical issue of particular relevance given the energy-constrained nature of the Kyrgyz power system, which brings substantial risk of power generation volatility and shortages during periods of water scarcity.

By focusing on strengthening power system security, the proposed goal also helps to address a potential gap in current policy-related activities to improve power sector reliability and resilience. At the same time, given the interrelated nature of power system security and adequacy, increasing the focus on power system security could also help to complement and strengthen the outcomes achieved through other activities aiming to improve the adequacy of electricity security. In these ways, the strategic goal provides a foundation for pursuing power system security that is consistent with Kyrgyzstan's wider electricity security and related socio-economic policy priorities. Overall, the proposed strategic goal has the potential to help accelerate roadmap development, simplify its implementation and maximise its effectiveness.

Potential policy measures

An effective policy roadmap will incorporate a mutually reinforcing set of policy measures to help achieve its goals. International experience suggests that the most effective approaches to improving power system security are built on an integrated set of proven and effective policy measures covering key issues including overarching system operation and management, supply-side initiatives, and demand-side initiatives.

Proposed measures should also reflect any practical constraints governing the wider operation and development of the power sector in Kyrgyzstan potentially including financial, technical, commercial, managerial and socio-economic dimensions. Ultimately, the roadmap will incorporate a limited number of key policy measures that offer the greatest potential to strengthen power system security consistent with achieving the roadmap goal.

System operation and management measures

International experience shows that the nature and effectiveness of system operation is a key determinant of power system security outcomes in practice. In Kyrgyzstan, the technical standards and operational protocols governing system operation and the management of power system security have changed little since independence, with technical aspects relating to regional power exchanges governed by the 1998 Parallel Operational Agreement between national system operators and the CAPS regional dispatch centre.[44]

Technical standards have been augmented by various policies enabling the government to intervene to manage power production and consumption in the event of an emergency or natural disaster, or when the physical safety or security of people, installations or system integrity is threatened. Under Kyrgyzstan's Electricity Law, interventions of this kind are to be implemented in a manner that minimises their impact on power sector operations and on power consumers. These provisions are complemented by the Rules for Use of Electrical Energy, which creates categories of reliability for power consumers. Those receiving the highest level of service reliability are eligible for uninterruptable power supply supported by separate, onsite backup generation.[45]

However, in practice, fundamental limitations of the power sector infrastructure have the potential to expose all electricity consumers to the risk of frequent service disruption. This is especially the case when the power system is under greatest stress during the winter peak season. A recent study noted that the system operator commonly runs key transmission network components well above their operational power flow ratings for sustained periods during winter to meet peak demand requirements.[46] Such practices suggest that the power system is often not operating in accordance with generally accepted power system security standards during periods when the power system is at greatest risk of experiencing a major power system security event. In the absence of major and rapid infrastructure development, which is highly unlikely given current financial constraints, international experience highlights several initiatives that could be pursued in the short to medium term to strengthen power system management and operation, to help strengthen power system security.

[44] See World Bank (2010b) for an overview of the key provisions of the 1998 Parallel Operating Agreement (as amended), including in relation to bilateral contracting, balancing, ancillary service provision and contingency reserve requirements.
[45] See IEA (2020), p. 9, for further discussion of these supplementary policies.
[46] Technical analysis undertaken by USAID in the context of its CAREM project has revealed substantial reliance on overloading of the 500 kV and 220 kV network to ensure service delivery during winter peak periods in Kyrgyzstan, with some 220 kV lines regularly operated at between 120% and 150% of their rated power flow capacity during periods of extreme demand.

In particular, there may be opportunities to more clearly define the system operator's role and responsibilities, especially regarding the nature and scope of its authority to intervene to manage sustained power system security events. Opportunities to improve operating practices, with greater emphasis on system-wide preparation, and co-ordination to support flexible, integrated real-time system management could also be explored. Effective real-time system operation also requires accurate and timely information and state-of-the-art technology to facilitate effective contingency planning, system monitoring, power flow management and co-ordinated emergency response. These issues are explored further below.

Operating practices

System operating practices are key determinants of power system security in practice. They translate the incentives created by the regulatory regime and security standards into protocols and practices that provide the means for delivering power system security.

Fundamental changes in power system capability and use, especially those resulting from the combination of deteriorating infrastructure and rapidly growing demand for power during the winter peak heating season, need to be appropriately reflected in operating practices if effective power system security is to be maintained. Protocols and practices governing contingency planning, real-time system operations and emergency management need to be updated on a regular basis to reflect these changing patterns of use and their evolving implications for maintaining power system security. Ideally, these activities should be undertaken from a whole-of-system perspective, potentially including more effective integration of transmission and distribution contingency planning, operations and emergency procedures where required. This may also include the operations of other key stakeholders whose actions can affect power system security, such as major generators and large loads.

System operating practices need to be flexible and adaptable to permit effective real-time management of power system security. International experience suggests that successful management of power system security is increasingly dependent on being able to effectively monitor, diagnose and respond to changing power system conditions in real time and over the course of a sustained emergency event.

To maintain effective situational awareness,[47] system operators and responsible parties need to have access to accurate information that provides sufficient

[47] *Situational awareness* in this context refers to the ability of system operators, and other responsible parties including network owners, generators and large loads, to effectively monitor, diagnose and respond to changing power system conditions in real time to maintain system security, effectively manage emergency conditions, and quickly and efficiently restore services following a power outage.

coverage of the power system to support effective monitoring and analysis of power system conditions in real time and over time. In Kyrgyzstan, this should include current and accurate information regarding the operational performance of key generators and network components, including information on water storage and flows which are critical for hydropower generation. In regional power systems spanning multiple control areas, such as CAPS, this should include ongoing real-time access to power flow data from across the integrated power system.

System operators or other parties responsible for managing power system security also need to be able to process this information quickly and effectively, to provide sufficient understanding to inform and adapt system operator interventions in real time and over time to manage power system security events. The capability, coverage and adaptability of energy management systems and other analytical tools used for contingency planning, power system monitoring and control, fault diagnosis, and emergency response will have a critical bearing on the effectiveness of power system security management in practice. Analytical tools and processes need to appropriately account for the potential influence of variability on power system security in this context. This is especially important in hydro-dependent power systems where periodic water shortages can significantly reduce power production capability for sustained periods.

Processes to review and develop system security standards and procedures should be undertaken on a regular basis to ensure their ongoing effectiveness. In particular, reviews should incorporate "stress testing" of procedures to ensure they can be deployed in a timely and effective manner in response to credible contingencies, especially contingencies associated with managing the impact of sustained water shortages on hydroelectric production during peak winter seasons. International experience suggests that active participation of all relevant stakeholders would help strengthen the credibility and effectiveness of a regular review and development programme.

Operating reserves and tools

System operators need to have access to sufficient contingency reserves and operating tools to be able to maintain power system security under a range of credible potential N-1 events. The nature and volume of reserves required will depend greatly on the topology of the power system, related power flows and the range of credible N-1 contingencies that need to be addressed.

For instance, a power system with limited network flow paths and capacity may contain a range of critical infrastructure points that will need to be appropriately managed from an N-1 perspective. Typically this may result in a higher proportion of total power system resources being deployed for system security purposes compared with more highly meshed and interconnected power systems. A larger proportion of power system resources may also be needed to ensure power system security in small or relatively isolated power systems, especially where maintaining power system security is dependent on the performance of one or two large generation or network elements. Similarly, hydro-dependent power systems that are exposed to periodic water scarcity may need a relatively large and diverse contingency reserve to manage exposure to the risk of periodic hydropower shortages.

Consideration should also be given to the nature of contingency reserves available for deployment and the extent to which they will enable system operators to effectively manage the range of credible threats to power system security. In Kyrgyzstan, high dependence on hydroelectric generation exposes the power system to periods of water scarcity which have the potential to seriously jeopardise power production during the peak winter season. This is a critical credible threat to power system reliability and resilience that an effective contingency reserve would need to be able to address.

International experience suggests that the most effective response in these circumstances would be to develop a contingency reserve based largely on thermal generation. Thermal generation provides a dispatchable source of power which is largely unaffected by water shortages. It can be strategically located adjacent to the main load centres, reducing the risk of network congestion unduly constraining power supplies. Also, it can be deployed as needed to offset any incremental loss of hydro production during periods of water scarcity. As a result, thermal generation possesses the technological and fuel diversity and the operational flexibility required to improve the reliability and resilience of a hydro-dependent power system during a period of water scarcity. Reserve capacity could be sourced from local thermal generators, or potentially from regional power suppliers where reserve-sharing arrangements can be relied upon to deliver on demand.

In addition, a growing range of smart grid technologies have the potential to greatly enhance power system security. In particular, these technologies have considerable potential to improve the accuracy, quality and timeliness of information and support the development of more accurate and dynamic system modelling to help strengthen contingency preparation and real-time system operator situational awareness. They can also greatly increase system operator control over power flows, providing scope to significantly reduce power system losses, while permitting more flexible operation of power systems and more effective real-time responses to manage emergency situations. Furthermore, they offer the potential to facilitate real-time co-ordination and more holistic management of system security in regional power systems spanning multiple control areas. Consideration could be given to further deployment of these technologies to help strengthen management of power system security, building on the initial projects undertaken with international partners.

Consideration could also be given to the nature and frequency of processes to review and test the effectiveness of emergency response resources. This could include "stress tests" of contingency reserve deployment, resilience and potential effectiveness in response to credible water scarcity scenarios.

Co-ordination and communication

In practice, responsibility for delivering power system security is shared among all parties with the capacity to affect the reliability and resilience of power supplies, potentially including system operators, generators, network owners, large loads and regulators. Only when each of these parties is undertaking its role in a co-ordinated manner can power system security be assured. Effective co-ordination is achieved when all responsible parties work together in a way that maximises efforts to improve power system security in real time and over the course of a sustained power system security event.

International experience suggests some key preconditions for achieving effective co-ordination of power system security. Roles and responsibilities for power system security need to be clearly defined, with individual and shared responsibilities identified, and potentially codified. The most effective arrangements typically seek to align accountabilities with role and function, so that the party best able to manage a power system security activity at least cost has the authority, means and incentive to act and can be held accountable for their actions. Codification of responsibilities, through legislation or regulation, can ensure that each party has clarity around its role and sufficient authority to undertake its responsibilities. It can also provide a strong incentive for effective co-ordination and information exchange within a national control area and across a regional power system spanning multiple control areas.[48]

Co-ordination during normal operating periods is usually supported by various institutional arrangements and processes to support ongoing engagement and information exchange between system operators and other responsible parties. Co-ordination is typically more actively managed during sustained power system security events, such as those resulting from periods of water scarcity in hydro-dependent power systems. During these events, ongoing arrangements are often enhanced through the deployment of emergency management teams that operate for the duration of the event.

[48] See IEA (2005a), pp. 108-122, for a discussion of the principles for establishing effective governance arrangements for power system security.

Similarly, co-ordination that facilitates more integrated real-time operation and emergency responses across the CAPS region has the potential to greatly improve contingency preparation and management of power system security events. Several regional power systems have developed multilateral frameworks and agreements incorporating protocols to facilitate more effective co-ordination of system operation before and during such events.[49] Opportunities may exist to build on and expand existing bilateral and multilateral approaches, including joint preparation of contingency plans among system operators within CAPS, with agreed protocols for co-ordinated action in the event of a major, sustained power system security event.

Effective co-ordination also requires good communication and information exchange, which provides an essential foundation for improving system operator situational awareness and maintaining effectively co-ordinated actions during sustained power system security events. Good communication among responsible parties needs to be based on accurate, timely and complete information exchange to support more effective operational contingency planning and power system security management. Consideration could be given to developing more comprehensive data and more effective data gathering capability, based on a clearly defined set of data requirements.

Similarly, the wider community will expect to be kept informed about events that affect the reliability of electricity services, especially during sustained emergency events. Experience suggests that communication strategies for engaging with the community need to be developed in advance and tested on a regular basis to ensure that they can be implemented quickly and effectively for the duration of a power system security event.

Training and capacity building

International experience highlights the importance of having highly trained and experienced system operators capable of quickly diagnosing and responding to power system security events. It also suggests that scope may exist to strengthen operators' capacity to identify and respond to alert conditions and actual events through appropriate training and certification.

System operator training programmes in Europe and North America are increasingly emphasising emergency management and co-ordination. Training programmes typically employ case studies and computer simulations based on actual power system security events or realistic credible contingencies. Most system operators are required to undertake at least five days of training each year.

[49] See ENTSO-E (2006) and ENTSO-E (2016) for further details about the leading practice Nordic regional power system operating agreement.

Consideration could be given to improving training programmes including by incorporating scenarios based on actual power system security events, wider use of simulators and emergency response exercises in training programmes, and developing joint training programmes to facilitate more effective co-ordination among system operators within the CAPS region.

Skill development could be complemented and reinforced through the adoption of a common certification process and competency standards for all system operators. Consideration could also be given to linking system operator certification to an ongoing process of continual education and assessment.

Advance planning and preparation for sustained emergency events

Leading practice hydro-dependent power systems typically have emergency management plans prepared in advance to support timely and effective deployment of supply and demand measures during sustained periods of water shortage.[50]

These plans generally incorporate clearly defined objectives, minimum dedicated reserve requirements and metrics for activation and cessation of emergency interventions based on key triggers determined in advance, such as changes in water flow and storage levels, and changes in supply-demand balances.

Clear and objective triggers for activation and cessation of emergency interventions will help to build certainty, predictability and confidence in the response regime. Triggers should be built on changes in supply-demand balances, or some other combination or underlying fundamentals. For example, New Zealand has developed a leading-practice system of triggers linking the probability of power shortages to changes in water flow and storage levels, with the results published as a simple and robust forward indicator showing the likelihood of emergency intervention in the following two months.[51] Objectivity can be further enhanced where the responsibility for declaring an intervention resides with an independent authority or is undertaken on the advice of an independent authority subject to clearly defined and predetermined activation criteria.

Plans should also address the roles and functions of the key stakeholders responsible for implementing the response to the extent required, including establishing overarching management responsibilities and arrangements, and mechanisms for co-ordination and co-operation among key stakeholders.

[50] See Transpower (2016a) for an excellent example of an integrated emergency management plan designed to address hydropower shortages resulting from sustained periods of drought.

[51] See Transpower (2021a); Transpower (2021b); and Transpower (2021c) for further explanation of New Zealand's framework for intervening during sustained emergency events caused by droughts.

International experience also suggests that plans should incorporate proportional responses that are calibrated in relation to the expected nature, impact and evolution of each event. This will help reduce the risk of intervention delivering unintended outcomes such as unduly prolonging restrictions, or increasing related administrative or economic costs.

Plans also need to be regularly tested to ensure they have the desired effect and can be implemented in a timely and effective manner. Resourcing, co-ordination and communication issues should be tested in this context. In particular, preparations and testing should ensure that all stakeholders with an implementation role understand their function, are appropriately resourced, and are prepared to undertake it in a co-ordinated manner to deliver an effective response. Preparedness exercises should be conducted on a regular basis to ensure that measures can be implemented smoothly and effectively at short notice and under emergency conditions.

Box 3 Proposed system operation and management measures

- Review and update system operating practices, with a view to identifying and addressing any gaps in current arrangements or opportunities to improve practices, data quality and coverage, and analytical methods used to manage power system security, especially during sustained power system security events resulting from water shortages.
- Review and upgrade operating reserves and tools to ensure that they provide system operators with the volume and diversity of resources and operational capabilities required to effectively monitor, analyse and intervene to manage changing power system conditions in real time and over the course of a sustained power system security event. Examine the potential to deploy smart grid technologies to help reduce power system losses.
- Review and update co-ordination and communication arrangements to ensure that all responsible parties understand their respective roles and are able to work together effectively to address a power system security event, and to keep other stakeholders and the wider community informed of developments in a timely manner.
- Review and upgrade training and capacity-building arrangements to support more effective management of power system security events. In particular, consider including case studies and simulations based on actual power system security events and credible contingencies. Reinforce training with operator certification and competency standards.

- Develop an integrated emergency management plan in advance to support more timely and effective management of sustained power system security events resulting from periods of water scarcity. The plan should include: clearly defined goals; objective, predetermined triggers for activating and ceasing emergency interventions; clearly defined roles and functions for responsible parties; and mechanisms for co-ordination and communication as required. The plan should be reviewed and tested on a regular basis to ensure it operates as expected and can be implemented quickly and effectively.

Supply-side measures

Supply-side measures are the primary means for managing power system security events, especially when those events are sustained over a longer period. Kyrgyzstan's approach to managing power system security events to date has typically relied heavily on supply-side interventions. For instance, Kyrgyzstan responded to a forecast hydropower production deficit of around 3 000 GWh for the 2021-2022 winter peak season with a range of supply-side measures. These measures included negotiating agreements to import: up to 900 GWh from the Republic of Kazakhstan; up to 750 GWh from the Republic of Uzbekistan; and up to 500 GWh from the Republic of Turkmenistan. In addition, generation from the Bishkek CHP facility increased by 2 000 GWh over the 2021-2022 winter period.[52]

International experience suggests that maintaining power system security in hydro-dependent power systems may require access to a range of supply-side resources beyond the usual contingency reserves set aside for normal operations. In hydro-dependent power systems it is common practice to establish dedicated contingency reserves designed to offset supply-demand imbalances resulting from water scarcity. For example, the Swedish transmission system operator (TSO) procures a strategic reserve each year to cover the winter peak heating season. The volume of the reserve is determined on the basis of winter power balance forecasts conducted annually in advance, covering a range of scenarios ranging from normal operating conditions up to a one-in-ten-year cold winter. Box 4 provides further details.

[52] Several media outlets reported the key features of the government's response. For example, see Kaktus Media (2021) for further details.

Box 4 Overview of the Swedish strategic reserve mechanism

Under the Swedish strategic reserve mechanism, Svenska Kraftnät (the Swedish TSO) procures strategic reserves for the winter season, covering the period from 15 November to 15 March. Reserves are purchased through an annual procurement process.

Reserves can be activated only in particular Nordpool pricing regions within Sweden, where winter imbalances may create a material risk to power system security that currently can be effectively addressed only through market intervention. Additionally, reserves can be activated only after all other commercial options have been exhausted.

The volume of reserves to be procured is determined each year on the basis of a series of power balance forecasts developed by the TSO for the forthcoming winter period. The winter power balance is highly sensitive to temperature, as electric space heating is the main driver of changes in consumption over the winter period. Hence, the power balance forecast reflects two key scenarios of winter consumption:

- a forecast of the power balance assuming normal winter temperatures.
- a forecast of the power balance assuming lower winter temperatures consistent with a one-in-ten-year event.

Source: IEA (2019a), *Energy Policies of IEA Countries – Sweden 2019 Review.*

In principle, contingency reserves should be sufficient to compensate for the loss of the largest power system generation or network element. In Kyrgyzstan, this would mean having sufficient reserves to make up for the loss of one of the Toktogul hydropower plant's four 300 MW generators, which are the largest generating units in the Naryn hydropower cascade, and the main 500 kV transmission line connecting production in the south with major consumption centres in the north of the country.

However, from a power system security perspective, the key risk to be managed in the Kyrgyz context would be a sustained emergency event caused by a severe water shortage that restricts hydropower production. In this case, the likely magnitude of an emergency supply deficit in the Kyrgyz power system will depend greatly on the severity and duration of the water shortage event. Time of year will also have an impact given that the majority of power consumption occurs during the winter months, coinciding with the greatest likelihood of water shortages affecting hydropower production.

Previous periods of acute water shortage suggest that the likely magnitude of hydropower loss during this kind of event may be well above the levels implied by a strict application of the N-1 standard. For example, in the water shortage event during 2015 and 2016, the average level of hydroelectric production fell by around 1 800 GWh per year compared with the ten-year average. This represented an annual deficit of around 13.6%. However, the impact was felt largely during the winter heating season when the water shortage was greatest and demand was at its annual peak. Using seasonal power consumption patterns in 2019 as a guide,[53] it is likely that that between 60% and 70% of the annual hydropower loss was realised during the winter heating seasons of 2015 and 2016. This implies that the magnitude of the supply response required at that time would have been between 1 050 GWh and 1 250 GWh for each winter heating season for the duration of this event. In annualised terms, this would have translated into a hydropower deficit during the winter period of between 16.4% and 19.1%.

Analysis of Naryn river water flows suggests that there's roughly a 50% chance of water inflows being sufficient to meet hydropower requirements in a normal operating year, with significant production shortages likely during a 1-in-20 dry year event.[54] Table 3 provides a simple sensitivity analysis of the potential implications for hydropower production and contingency reserve requirements associated with a range of possible water shortage events during the winter heating season.

Table 3 Sensitivity analysis of hydro production and contingency requirements during winter water shortages

Annual hydropower production loss (% of 10-year average)	Estimated annual electricity production loss (GWh)	Estimated electricity loss during winter (GWh)	Estimated winter contingency requirement (MW)
10%	1 308	850	195
20%	2 616	1 700	389
30%	3 924	2 551	584
40%	5 232	3 401	778
50%	6 540	4 251	973

Sources: Author's calculations based on data provided in IEA (2022), *World Energy Statistics and Balances* (database); and JSC National Settlement Center (2021), Monthly Electricity Balance of Kyrgyzstan's Power System - 2020 Database.

[53] In 2019, around 65% of annual electricity consumption for the residential, industrial and public sectors (representing around 86% of total final power consumption in 2019) occurred during the winter months, implying that any loss of power production would have a proportionally greater effect during the winter period. Relative consumption proportions recorded in 2019 were applied to estimate the likely impact of reduced power production during the winter months in 2015-2016. See JSC National Settlement Center (2021) for details.

[54] These findings reflect historical analysis of water flows into the Naryn river system and the Toktogul reservoir conducted by USAID in the context of undertaking a review of the Kyrgyz government's action plan to address winter power shortages in 2008-2009.

Recent experience suggests that one-in-ten-year water shortages can translate into a reduction in hydroelectric production of between 20% and 40% during the winter peak heating season. Based on the sensitivity analysis presented in Table 3, this suggests that an effective contingency reserve would need to be able to cover the loss of between 1 700 GWh and 3 400 GWh of hydro production in any given winter period, which translates into a minimum contingency reserve of around 780 MW.

International experience suggests that a wide range of supply-side measures could be included as part of a national contingency reserve. Some common examples are identified in Table 4.

Table 4 International examples of supply-side measures used during emergency events

Measure	Description	Deployment timeframe	Deployment issues
Increase power infrastructure capacity	Increasing overall power sector capacity by improving the operation of existing equipment, rehabilitating retired or 'mothballed' generation, and relaxing technical operating standards for short periods.	From weeks up to 6 months	Cost, refurbishment requirements, feasibility and capability to implement quickly.
Deploy existing CHP plants	Large-scale combined heat and power (CHP) plants used for district heating purposes can be deployed to produce electricity, especially where capacity is available or where capacity is idle during warmer months.	From weeks up to 6 months	Operational costs, fuel access, duration, capacity to operate in condenser mode, feasibility of implementation, ability to seamlessly integrate into power system.
Offer 'premium' power purchase contracts	Procure additional supply at short notice by offering short-term bilateral power purchase contracts at premium prices to domestic and (possibly) regional power producers, targeting 'back-up' generation.	From weeks up to 6 months	Cost, duration, counterparty targeting and feasibility of implementation.
Deploy high speed reciprocating engines	High speed reciprocating engines are a form of internal combustion engine that is relatively thermally efficient and can be readily deployed for short periods to produce electricity.	From weeks up to 6 months	Availability, cost (fuel and rental), capacity to deploy quickly, ability to seamlessly integrate into power system and operations.
Deploy leased generators	A range of generation has been leased to boost supply during sustained events including: mobile generators mounted on barges; mobile generators mounted on trucks; ship-mounted turbines; and open-cycle gas turbines.	From weeks up to 24 months	Availability, cost (fuel and rental), capacity to deploy quickly, ability to seamlessly integrate into power system and operations.

Measure	Description	Deployment timeframe	Deployment issues
Increase power infrastructure availability	Increasing generation and network availability to help increase effective output, including by increasing utilization of non-hydro generation plants and reducing planned outages.	Up to 6 months	Equipment availability, operational constraints and limitations.
Deploy new capacitor banks	Strategic deployment of additional capacitor banks at key sites can reduce transmission system losses and increase the effective operating capacity of existing generators.	From 6 months up to 24 months	Cost, availability, capacity to deploy quickly, ability to seamlessly integrate into power system and operations.
Deploy advanced grid management systems	Deployment of 'smart' grid technologies and advanced metering systems can help to improve real-time power system monitoring and management, and help to reduce technical and non-technical losses.	From 6 months up to 24 months	Cost, availability, capacity to deploy quickly, ability to seamlessly integrate into power system and operations, public acceptance.
Install used generators	Second hand generators, such as open-cycle gas turbines, can be deployed more quickly than new plant and typically at much lower cost. However, operational performance may not be guaranteed.	From 6 months up to 24 months	Availability, cost (capital and fuel), operational reliability, capacity to deploy quickly, ability to seamlessly integrate into power system and operations.
Accelerate completion of new infrastructure	Undertaking activities to bring forward the planned commissioning of generation plants and power lines currently under construction, or prevent schedule slippages.	Up to 24 months	Availability, cost and practical constraints on accelerating construction schedules.

Sources: Adapted from ESMAP (2011), Managing an Electricity Shortfall – A Guide for Policymakers; and World Bank (2010a), *Managing an Electricity Shortfall.*

Domestic supply-side responses could be complemented with supplies imported from regional power producers. In principle, integrated regional power systems have the potential to strengthen power system reliability at least cost, through more effective sharing of reserve capacity, allowing system operators to draw on the reserves and resources of adjacent control areas to ensure reliable and secure system operation. In particular, it can improve management of frequency control and provide access to additional generating capacity to help stabilise the supply-demand balance during sustained emergency events.

The potential benefits for power system security are enhanced where greater integration allows for more effective deployment of complementary generation technologies. For instance, greater integration of hydro-based power systems with thermal-based power systems can strengthen security of supply in the hydro-based system during a drought. At the same time, greater integration of a hydro-based system with a thermal-based system can improve the operational resilience and flexibility of the thermal system, enabling more timely and effective responses to manage real-time changes in load. The reliability benefits of such integration were clearly demonstrated during the 2002-2003 winter in the largely hydro-based Nordic regional power system, which was able to maintain uninterrupted power supplies despite experiencing a 1-in-200 year drought.[55]

As previously noted, CAPS was originally designed for this purpose, among other things. However, decades of regional power system fragmentation has greatly eroded the effectiveness of these arrangements. As a result, at present Kyrgyzstan has ad hoc access to limited regional reserve sharing. Opportunities exist to build on this foundation through more formalised arrangements that involve greater integration of contingency preparation and operational management of power system security across CAPS.

For instance, one leading practice example is the Nordic Regional Security Coordinator (RSC). Nordic TSOs have recognised the benefits of greater regional co-operation and have developed the RSC to facilitate more efficient, timely and cost-effective management of power system security across the Nordic region. Box 5 provides further details.

Box 5 Overview of the Nordic Regional Security Coordinator mechanism

The Nordic RSC was established in 2018 by four Nordic TSOs to support them in maintaining the regional power system.

The RSC looks at power system security from a regional perspective and can issue recommendations to the national TSOs. Its functions include:

- Co-ordinated calculation of cross-border transmission capacity.
- Co-ordinated security analysis to identify preventive action for the individual TSOs.
- Outage planning co-ordination through a joint register and streamlined maintenance.
- Short- and medium-term adequacy forecasts for market players.
- Improved individual grid models and a common grid model.

Source: IEA (2019a), *Energy Policies of IEA Countries – Sweden 2019 Review.*

Choices in relation to the combination of supply-side responses to develop and deploy will depend on a range of factors including: the nature and expected

[55] See IEA (2005c), pp.164-169, for further discussion.

duration of power system security events; the relative cost and availability of supply-side options; the capacity to develop and effectively deploy those options; and the anticipated time frame for their deployment. Given these considerations, and given the hydro-dependent nature of the Kyrgyz power system, it is likely that the most feasible and effective approach would rely on a combination of supply-side measures based on local thermal generation.

One option would be to build a dedicated thermal generation plant with sufficient capacity to offset any potential reduction in hydropower production during periods of water scarcity. Such responses have been implemented in other hydro-dependent power systems around the world. Although appealing, such an option is unlikely to provide a timely or cost-effective response to the immediate power system security threat in Kyrgyzstan. A more cost-effective and feasible supply-side response may be to develop a contingency reserve drawing from existing assets.

For example, the Bishkek thermal CHP plant possesses considerable underutilised generating capacity; provides technological and fuel diversity, improving overall power system resilience; and is located close to major electricity loads, helping to reduce exposure to network-related delivery risks. Accordingly, it has the potential to provide much of the electricity needed to offset any hydroelectric production losses during a winter water shortage. Consideration could be given to reserving a portion of its generating capacity for the capacity reserve on an ongoing basis, especially in the short term while other options are being developed.

However, for Bishkek co-generation to provide an effective capacity reserve, it would need to be well maintained and have sufficient ongoing fuel reserves to ensure that it could be deployed to produce electricity at short notice with a high degree of reliability throughout the year, and especially during the winter peak season. Meeting this expectation in practice on an ongoing basis could prove expensive and problematic.

Ultimately, combining this measure with a range of other complementary and reinforcing supply-side measures could help to reduce the overall cost of maintaining an effective contingency reserve. It could also improve the reliability and resilience of the supply-side response by spreading the operational delivery risks across several different measures. Given Kyrgyzstan's circumstances and based on the menu of options identified in Table 4, potential complementary measures may include:

- Securing contingency reserves through permanent regional reserve-sharing agreements, calibrated on an annual basis to reflect projected changes in water resources.

- Sourcing surge capacity through contracting with domestic distributed generation and suppliers of mobile generation.
- Undertaking a range of targeted smart grid investments to reduce losses and improve the operational flexibility and resilience of power system operation, enabling the system operator to maximise output when supply-demand balances are under stress during periods of water shortage.

Many of the other supply-side options identified in Table 4 merit further examination. However, they are unlikely to be very effective or readily deployable in Kyrgyzstan in a timely or cost-effective manner in the short term.

Practical challenges associated with funding and immediately establishing a dedicated ongoing contingency reserve of the magnitude implied in the earlier sensitivity analysis of hydro production requirements could be greatly reduced by adopting a phased implementation strategy. For example, implementation could be divided into three stages, with the first stage proceeding immediately based largely on requisitioning capacity from Bishkek CHP. Subsequent stages could proceed in sequence at three-year intervals.

An approach of this kind would help to make the reserve more affordable by spreading the implementation cost across a much longer period of up to ten years, while greatly reducing the potential logistical challenges and risks associated with a more accelerated implementation plan. It would also facilitate the inclusion of potentially cost-effective supply-side options that may take longer to materialise, such as permanent regional reserve-sharing agreements, contracting with domestic distributed generators or incorporating capacity associated with a proposed second Bishkek CHP plant.[56] In addition, it would allow time to develop a more diversified portfolio of supply-side options, which would help to increase the operational flexibility and resilience of reserve.

Box 6 Proposed supply-side measures

- Develop and implement a dedicated contingency reserve calibrated to offset potential supply-demand imbalances resulting from the loss of hydropower during sustained periods of water scarcity. Include supply-side measures that are readily available, controllable, highly reliable, cost-effective and deployable at short notice.

[56] Recent press reports suggest that a long-dormant project to build a second Bishkek CHP plant may be revived. It is understood that the project would involve constructing a new 460 MW, gas-fired facility on the western outskirts of Bishkek. A two- to five-year construction period is envisaged at this stage. Details regarding a tender process for the development of a pre-feasibility study are expected to be announced shortly. See KyrgyzKabar News Agency (2021) for further details.

- Examine the potential to reserve a portion of Bishkek CHP's generating capacity for the contingency reserve. If feasible to proceed, take steps to incorporate this capacity as a primary response component of the contingency reserve.
- Examine and incorporate other supply-side options to complement and reinforce primary reliance on the domestic thermal generation contingency reserve including permanent regional reserve-sharing agreements, contracting for surge capacity, and undertaking targeted smart grid investments to reduce losses and improve power system operation during periods of water scarcity.
- Develop and implement a scenario methodology for assessing contingency reserve requirements that takes account of changes in winter water availability and heating demand. Update the scenarios annually, and use the results to inform decisions around the annual procurement of the contingency reserve.
- Explore the potential for strengthening regional management of power system security and take steps to formalise procedures and arrangements with regional partners in the longer term.

Demand-side measures

Traditionally, demand-side management in the power sector has relied on a range of regulatory measures and interventions, such as rotating load shedding, which are generally deployed in the short term to help manage power system security events. Utilities typically deploy demand-side measures to complement and reinforce supply-side measures in these circumstances. Demand-side measures have also been deployed in to help manage daily, weekly and seasonal periods of peak consumption that create tight supply-demand conditions that could threaten power system security. In Kyrgyzstan to date, regulatory demand-side measures have usually been deployed as a mandatory emergency intervention of last resort when power system security is under threat and all available supply-side reserves have been fully committed.

International experience shows that measures to reduce demand can be deployed quickly, deliver substantial immediate savings[57] and are among the most flexible resources available to help address power system imbalances, especially in hydro-dependent power systems during periods of water scarcity. Even relatively small volumes of demand restraint can substantially increase power system flexibility, reliability and resilience during these events.

[57] Emergency demand-side measures delivered power savings of between 10% and 20% during the hydrological shortage events identified in Table 1. See IEA (2011a), p. 8, for details.

Demand-side measures can provide a more flexible and efficient alternative to mandatory load shedding during emergency situations. Also, greater demand flexibility may reduce the volume of operating reserves required to deliver power system security, significantly reducing the cost of providing these services. Demand response can be fully activated over a very short time frame, making it an ideal alternative source of operating reserve, which can help to deepen and diversify the pool of reserves, improving overall contingency reserve flexibility and resilience. This could have the effect of improving overall power system security, while also having the potential to defer the need for incremental reliability-based infrastructure investments.

The reliability, flexibility and resilience benefits for power systems from implementing effective demand-side measures were shown in the aftermath of the 2011 Great East Japan Earthquake, where the resulting electricity savings enabled eastern Japan to avoid power cuts throughout the summer peak period. The main demand-side measures deployed are identified in Box 7.

Box 7 Demand-side measures following the 2011 Great East Japan Earthquake

In the wake of this event, Tokyo Electricity Power (TEPCO) lost around 40% of its generating capacity. At the time, TEPCO supplied electricity to around 42 million individual consumers and to corporations responsible for 40% of Japan's GDP.

The Japanese government implemented a series of mandatory and voluntary savings measures to help address the shortfall, including:

- Ten days of rotating load shedding immediately after the incident.
- Mandatory requirements for large industrial consumers to reduce electricity use by 15% (compared with the previous year) during July-September 2011.
- Measures encouraging small businesses to take voluntary power-saving actions.
- Measures encouraging households to take voluntary power-saving measures, including using electric fans instead of air conditioners, using blinds to reduce heat from sunlight, and disconnecting electric appliances when not in use.
- A range of public-sector energy-saving actions, including dimming/switching off lights, raising air-conditioning temperatures, and less frequent trains and metro services.

As a result of applying these measures, summer peak power demand fell by around 15%, which helped eastern Japan avoid unscheduled power restrictions.

Sources: Adapted from IEA (2019b), *Multiple Benefits of Energy Efficiency*; and IEA (2012), *World Energy Outlook 2012*.

However, the potential for demand-side measures to help strengthen power system reliability and security remains largely untapped in most power systems, including in Kyrgyzstan.

Several potential demand-side measures could be considered to complement and reinforce supply-side measures in this context including various forms of rationing, measures to encourage behavioural change, rapid deployment of some energy efficiency practices and technologies, and substituting electricity consumption.

Rationing

Mandatory rationing of power consumption provides the most direct and immediate means of moderating demand during an emergency event.

Rotating load shedding is the most common form of power consumption rationing applied by system operators during emergencies. It is relatively simple to implement using existing power system management infrastructure and can be done in a technically efficient and timely manner that directly responds to power system security requirements in real time. However, from a consumers' perspective, it is often done with limited knowledge and warning, and in ways that may not reflect wider socio-economic or community priorities or interests. As a result, this form of power rationing can be economically inefficient and rapidly become unpopular, placing substantial limitations on its use during sustained power system security events.

Leading-practice jurisdictions have sought to address these issues by transparently developing load-shedding protocols that seek to minimise their unintended socio-economic impacts to the greatest extent possible. Protocols are typically developed in close consultation with major power users and updated on a regular basis by responsible parties to reflect changes in power consumption patterns and use. They are implemented in a co-ordinated manner, in close consultation with major users, according to predetermined criteria that establish the system preconditions for deploying rotating load shedding and the potential duration of its deployment during sustained events.

For example, New Zealand has established rolling outage plans that are fully integrated with the overarching emergency management plan for responding to a loss of hydroelectric production resulting from sustained drought conditions. Under these arrangements, the system operator is required to issue a supply shortage declaration before it is able to activate rolling outage plans in response to sustained power system security events. Supply shortage declarations need to meet clearly specified criteria for activation and provide at least 14 days' notice to major affected users before activation. In addition, declarations may include specified electricity consumption savings targets for large users.[58]

Mandatory consumption rationing is also often delivered through various administrative or regulatory mechanisms. They typically take the form of a consumption-saving target or quota that is specified by consumer class, quantity consumed or location. Such instruments can be more effectively calibrated to reflect economic and community priorities compared with load-shedding mechanisms. However, these kinds of administrative mechanisms can still deliver poor outcomes with significant economic and social costs, especially where the mandated savings targets unduly disadvantage poor or vulnerable consumers with limited capacity to respond. In practice, these kinds of equity issues are usually addressed through some form of carefully targeted compensation mechanism operating in tandem with the rationing mechanism.

Opportunities to review and update mandatory consumption rationing mechanisms and load-shedding protocols could be considered, with a view to improving their scope for deployment and effectiveness in response to sustained power system security events.

Behavioural change

A range of demand-side measures have been deployed during emergency events to encourage behavioural change that has delivered substantial reductions in power consumption for short periods. Measures to encourage power savings during emergency events typically rely on voluntary measures, innovative contracting or scarcity pricing.

International experience shows that calls for voluntary energy savings can substantially reduce demand for short periods during emergency events, creating greater system flexibility and resilience in the wake of a power system disruption. To date, most efforts to harness voluntary power savings during shortages or emergency events have focused on information and media campaigns to inform consumers and encourage them to adopt behaviours to reduce power consumption.

A wide range of demand-side savings measures have been successfully promoted through information campaigns during emergency events. Table 5 identifies several.

[58] See Transpower (2016b) for further details.

Table 5 Demand-side measures promoted through information campaigns

Demand-side measure	Target sector
Reset thermostats to reduce heating or cooling demand	All
Turn off non-essential lighting	All
Switch-off or activate power management features on unused computers	All
Switch from electric heating to fuel heating	All
Reduce shower time and take fewer baths	Residential
Dry clothes on line rather than with dryer	Residential
Practice more efficient dishwashing	Residential and commercial
Practice more efficient clothes washing	Residential and commercial
Lower water heater storage tank temperature	Residential and commercial
Correctly regulate hot water circulation pumps for boilers	Residential and commercial
Unplug appliances when not in use (to reduce standby power consumption)	Residential and commercial
Reduce elevator or escalator speed	Public and commercial
Switch off alternating street lights	Public
Switch traffic signals to flashing during low-traffic periods	Public
Eliminate leaks in pressurized air systems	Industrial
Replace belt drives on motor systems	Industrial
Schedule shut-downs during critical power consumption periods	Industrial
Shift production to outside of the electricity shortfall area	Industrial

Source: Adapted from IEA (2011a), *Saving Electricity in a Hurry: 2011 Update*.

These measures cover electricity-consuming sectors that represented nearly all of Kyrgyzstan's power consumption in 2019, with a focus on residential and industrial consumption, which together represented nearly 90% of total final electricity consumption in that year. This suggests that information campaigns highlighting an appropriate combination of these voluntary saving measures have the potential to be effective in Kyrgyzstan.

However, realising this potential during a crisis can prove challenging in practice. International experience suggests some key steps for developing and implementing successful voluntary savings campaigns including:

- Identifying key consumer sectors, their power saving potential and priorities for voluntary saving during a sustained power system security event.
- Understanding the factors that influence consumption decisions and how best to motivate behavioural changes to save power within each targeted consumer sector.

- Based on this understanding, developing and implementing an integrated information and communications strategy that:
  - Clearly communicates relevant facts and what consumers in each target sector can (or must) do to help.
  - Is based on simple, clear messaging that resonates with the target audience.
  - Appropriately combines mass media, print media and social media to maximise influence and coverage.

International experience suggests that the most effective programmes to harness voluntary electricity savings during an emergency are prepared in advance and ready to be rolled out quickly when required.

Incentives for voluntary demand-side savings could be strengthened through various forms of innovative contracting. For example, a range of incentive-based contractual arrangements have been deployed internationally to help harness electricity savings during periods when power systems are under stress or experiencing emergency conditions. Several are identified in Box 8.

Box 8 Contractual mechanisms to harness power savings

- **Direct load control programmes** permit operators to enter into contracts with customers, enabling them to remotely shut down or cycle a customer's electrical equipment (e.g. air conditioners, water heaters, space heating) at short notice. Direct load control programmes are offered primarily to residential and small commercial customers.
- **Interruptible supply contracts** incorporate curtailment options and provide a rate discount for agreeing to reduce load during predefined events. Penalties may be incurred for failure to curtail. Interruptible programmes have traditionally been offered to large industrial and commercial customers.
- **Demand bidding and buyback programmes** enable customers to make bids to curtail, based on wholesale electricity market prices or an equivalent benchmark. Such products are usually made available to large customers only, with metering equipment that permits real-time monitoring and verification of compliance.
- **Emergency demand response programmes** provide incentive payments to customers for load reductions during periods of reserve shortfalls.
- **Capacity market programmes** accept bids from customers to curtail load as an alternative to procuring conventional generation or network resources. Customers typically receive same-day notice of events. Incentives usually consist of upfront reservation payments, and penalties for failure to curtail when required.

- **Ancillary services programmes** permit customers to bilaterally contract to deliver curtailment, or to offer load curtailment in ancillary service markets as an alternative source of reserves for system operators. Where available, system operators pay customers the contract price (or market price in the case of an ancillary services market) for committing to curtail loads according to contract or dispatch requirements.

Source: IEA (2011b), *Empowering Customer Choice in Electricity Markets*.

Technologies to monitor and verify demand response in real time, such as smart metering and controllable devices, are generally deployed to enforce these contractual arrangements. The contracting party, usually a retailer, system operator, aggregator or other load-serving entity, makes the decision to activate these demand-side measures. Payments to customers are usually agreed in advance of any event that may trigger activation. Consideration could be given to developing innovative contractual arrangements such as these to help turn voluntary demand-side savings into a potential emergency management resource that could be procured by the system operator, or other responsible parties, to complement and reinforce traditional supply-side resources.

Alternatively, raising power prices to scarcity levels could provide a clear and effective incentive to reduce power consumption during periods when power systems are under stress or experiencing emergency conditions. The effectiveness of price signals in moderating demand during an emergency event depends very much on whether consumers are exposed to the price rise in real time and whether they have the capacity to respond.

If consumers are not aware that scarcity pricing is in effect, they will have no incentive to respond and their consumption is unlikely to change. In this situation, dramatic power cost increases can create unintended financial hardship. Similarly, when consumption is highly price-inelastic,[59] exposure to scarcity pricing may simply result in a wealth transfer from consumers to producers without achieving the desired reduction in consumption. Care needs to be taken to ensure that any scarcity price mechanism is deployed appropriately and sends an effective signal to reduce, delay or defer consumption. It is unlikely that wide application of scarcity pricing beyond some large users would represent a practical or feasible option for Kyrgyzstan in the near term given current regulated tariff arrangements.

[59] Consumption is said to be price-inelastic when the rate of change in consumption is relatively unresponsive to the rate of change in price.

Energy efficiency and electricity substitution

Many energy efficiency and electricity substitution measures that could substantially reduce power consumption require significant capital investment and take time to implement. Hence, they are unlikely to offer a practical option to reduce power consumption over the relatively short duration of a typical power supply shortage resulting from a sustained period of water scarcity. Such measures are usually best pursued as part of an ongoing strategy to efficiently moderate and reduce power consumption over the longer term.

However, international experience suggests that there are some energy efficiency and substitution measures that have the potential to deliver significant power savings in the short term.

In particular, the rapid deployment of energy-efficient lighting technologies, such as compact fluorescent lamps (CFLs) and light-emitting diodes (LEDs), may provide a practical and cost-effective option for significantly reducing residential power consumption in the lead-up to, and during, a sustained power system security event. A World Bank study of the impact of deploying energy-efficient light bulbs on household electricity consumption in Kyrgyzstan found that switching four incandescent light bulbs to CFLs could save households up to 60 kWh per month, or around 10% of average monthly household consumption in 2016. Furthermore, given that lighting is commonly used during the daily peak consumption period, the majority of these savings are likely to accrue when the power system is under greatest stress. As a result, these savings also have the potential to significantly improve the operational reliability and resilience of the distribution system, which can serve to strengthen overall power system security.[60]

Given that the residential sector uses over 70% of the power consumed in Kyrgyzstan, there may be considerable potential for a timely energy-efficient lighting replacement programme to substantially contribute to reducing demand during a sustained power system security event, especially over the winter period.

Opportunities may also exist to harness power savings in the short term through demand-side measures targeting space heating, especially in the residential sector. Space heating is a major driver of total final power consumption during the winter season, which suggests that savings from more efficient heating, or substitution of electric heating with other forms of space heating, could make a valuable contribution to improving power system security during a sustained winter season hydrological event.

[60] See Carranza and Meeks (2016) for further details.

For example, recent World Bank analysis concluded that residential building insulation in Kyrgyzstan is generally poor with considerable scope for improvement.[61] Improving building insulation and weatherisation has the potential to greatly improve space heating efficiency and reduce electricity consumption during the peak winter heating season. A practical initial measure could focus on education and awareness-raising. This measure could include local weatherisation initiatives offering in-home advice to improve management of power consumption, potentially including providing some low-cost items such as door and window sealers to demonstrate cost-effective and readily available opportunities to improve space heating efficiency. Such initiatives may also build greater willingness to participate in voluntary demand-side programmes to reduce power consumption during future sustained emergency events. More expansive building retrofit and space heating appliance replacement programmes could be deployed to incrementally improve building and space heating energy efficiency in the longer term.

Another possibility may include encouraging switching to alternative forms of space heating. For instance, district heating may represent a practical alternative in urban areas, especially for medium-density residential, commercial or public buildings with a dormant or readily accessible network connection. Similarly, high-efficient, low-emission heating options may provide a feasible substitute for electric space heating in some circumstances.[62] However, it is likely that both options would require significant capital expenditure and take some time to deliver. As a result, neither of these options is likely to deliver appreciable power savings over the relatively short duration of a winter water shortage event. A longer time frame would be required to deliver substantial savings.

Other possibilities to help manage and reduce power consumption that could be deployed in the lead-up to, and during, a sustained emergency event may include deploying more energy-efficient appliances, installation of direct load control devices for significant power-consuming appliances and equipment, and retrofitting and servicing electric motors to improve their operational efficiency. Although the potential for cost-effective, large-scale deployment of these options during a sustained power system security event may be limited in practice, these options may offer considerable potential for ongoing power savings and improving the operational flexibility and resilience of the power system over the longer term.

[61] See World Bank (2020), pp. 8-11, for further details.
[62] See World Bank (2020) for further discussion of the high-efficient, low-emission heating demonstration programme undertaken as part of the Heat Supply Improvement Project.

Box 9 Proposed demand-side measures

- Review and update mandatory consumption rationing mechanisms and load-shedding protocols to improve their scope for deployment and effectiveness in response to sustained power system security events.
- Establish a comprehensive communications and media strategy in advance that is ready to deploy to targeted stakeholders and consumers to effectively inform them about power-saving opportunities, to encourage them to participate in voluntary power-saving activities and to build ongoing community support for necessary interventions during a sustained power system security event.
- Develop a range of contractual mechanisms to help harness power savings during sustained power system security events.
- Explore the potential to deploy scarcity pricing to help moderate demand among targeted large-scale users during sustained power system security events.
- Develop and implement complementary measures to improve the efficiency of power consumption and to encourage substitution of power consumption during sustained power system security events, initially focusing on opportunities for cost-effective and timely deployment of energy-efficient lighting, building insulation improvements and space heating alternatives. Develop and implement ongoing energy efficiency and substitution strategies for the power sector over the longer term, targeting the residential, industrial and public sectors.
- Prepare a demand-side measures strategy for the power sector that is ready to deploy during sustained power system security events. The strategy should provide an integrated framework for deploying all proposed demand-side measures, including communications, regulatory mechanisms, energy efficiency and power substitution programmes, contractual mechanisms, voluntary mechanisms, and (potentially) pricing mechanisms. Implementation procedures should be tested regularly with all key stakeholders to ensure the strategy can be deployed quickly and efficiently in the lead-up to, and during, an emergency event.

Pathways for strengthening power system security in Kyrgyzstan

Key elements of an integrated, strategic policy roadmap for strengthening power system security in Kyrgyzstan over the next decade are presented in Table 6.

Table 6 Potential pathways to strengthen power system security in Kyrgyzstan

STRATEGIC PRIORITIES	PROPOSED MEASURES		2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
System Operation & Management	Review & update system operating practices											
	Review & upgrade system operating tools											
	Review & upgrade coordination & communication arrangements											
	Review & upgrade training & capacity building arrangements											
	Develop an integrated emergency management plan for responding to sustained emergency events											
Supply-side	Develop & implement a dedicated contingency reserve	Stage 1										
		Stage 2										
		Stage 3										
	Develop & implement a scenario-based methodology for assessing contingency reserve requirements											
	Develop & formalize arrangements to strengthen regional management of power system security											
Demand-side	Review & update mandatory power rationing and load shedding arrangements											
	Establish a communication & media strategy to inform power consumers & encourage voluntary power savings during sustained emergency events											
	Develop contractual mechanisms to harness power savings during sustained emergency events											
	Develop complementary policies & measures to promote energy efficiency & efficient substitution of power consumption	Emergency Response										
		Ongoing										
	Develop initiatives for deploying scarcity pricing to moderate demand among large users during sustained emergency events											
	Develop an integrated strategy to support timely & effective deployment of all demand-side measures during a sustained emergency event											

Development phase: Implementation phase: Operational phase:

The roadmap seeks to achieve the proposed strategic goal of improving power sector reliability and resilience by quickly strengthening power system security responses to sustained hydrological events, by deploying an interrelated set of policy measures that focus on achieving three strategic priorities:

- improving power system operation and management, especially in response to sustained hydrological events.
- broadening and deepening supply-side capability to respond to sustained hydrological events.

- developing complementary demand-side capability that can be deployed effectively during sustained hydrological events.

Pathways for developing and deploying each proposed measure are identified in the roadmap, along with indicative milestones for each of the main phases of the roadmap including the:

- **Development phase** (red cells), which focuses on the initial policy development process including analysing and reviewing existing arrangements to identify gaps and development opportunities, culminating in the formulation of specific policies and proposals to determine the nature and scope of the measure to be deployed and to guide subsequent implementation and operation.
- **Implementation phase** (orange cells), which focuses on operationalising policies. Detailed implementation arrangements would be developed and finalised during this period, including related operational policy, legal, regulatory, funding and programme delivery matters. This may also include potential preliminary implementation arrangements such as pilot or demonstration programmes. Preliminary implementation programmes are typically undertaken to support incremental learning and risk management, especially when measures introduce new processes, are potentially sensitive, or are in some other way groundbreaking.
- **Operational phase** (green cells), which commences when each measure is ready for full deployment in response to a sustained power system security event. It is envisaged that incremental development of measures will continue on an ongoing basis to ensure that they reflect experience and remain effective over time.

It is envisaged that most of the proposed measures could be developed quickly in parallel, with the objective of deploying them in the first two to three years of the programme. This reflects the integrated nature of several of the measures; the critical need to implement some measures quickly to provide a sound foundation for progressing other elements of the programme; the likely moderate cost of implementing most of these process-based measures; and the relative ease with which they could be developed and deployed, building on existing institutions, knowledge and experience. Accordingly, it is proposed to front-end-load much of the development and implementation activity, reflecting the urgent need to address the related power system security challenges facing Kyrgyzstan.

By contrast, most of the measures proposed for medium- or longer-term deployment are likely to raise a range of challenges that may require additional time to resolve. For instance, several of these proposed measures are likely to be complex to develop and implement, may require sensitive and time-consuming negotiation to progress, and may involve considerable capital expenditure and construction lead times. The proposed roadmap has sought to appropriately reflect these practical considerations.

An integrated set of measures is proposed to improve the system operator's capability to manage sustained power system security events resulting from periods of water scarcity. These include upgrading operating practices, improving co-ordination and communication arrangements, and upgrading training and capacity-building programmes, which are essentially based on process improvement with the potential to proceed relatively quickly. The development and implementation of the operating practice measure would benefit from close co-ordination with the development of other related measures including the measure to update mandatory rationing and load-shedding arrangements, which is one of the demand-side priority activities, and the scenario-based modelling of contingency reserve measure, which is one of the supply-side priority activities.

Upgrading the system operator's monitoring, analysis and real-time management tools and capabilities is a key proposed measure in this context, which offers the potential to substantially reduce power system losses and to greatly improve management of sustained hydrological events. However, implementation of this measure is likely to rely on the deployment of significant technological and capital upgrades which could prove complex, time-consuming and expensive to develop and implement in practice. These practical considerations are reflected in the period allocated in the roadmap for undertaking these activities. Another key measure is the proposed development of an integrated emergency management plan, which has the potential to support more effective, timely and co-ordinated management of sustained hydrological events in the future. Development and implementation of this measure should proceed as a priority.

Supply-side measures represent the backbone of the roadmap, providing the primary response and main resources for managing sustained power system security events. The sensitivity analysis presented in Table 3 suggests that an effective winter contingency reserve able to offset a credible sustained hydrological event would ultimately need to be in the order of at least 780 MW. This would represent a considerable investment of capacity and financial resources. It would be unrealistic to expect this level of contingency reserve to be developed and deployed in the short term. Hence, the roadmap proposes a three-stage approach to its development.

The first stage would involve securing a working reserve drawing from existing infrastructure. A potentially ideal candidate could be a portion of the underutilised generating capacity associated with the Bishkek CHP plant. This plant has the potential to become a readily available source of thermal generation, which is strategically located close to major loads, with the potential to be quickly deployed as an effective source of emergency power to offset the loss of hydroelectric power for the duration of a periodic seasonal hydrological shortage. As a result, it is potentially well placed to immediately contribute to the contingency reserve, which is reflected in the relatively short time frame proposed for deploying the first stage of the measure. Ideally, this first stage would aim to secure around 40% of the total capacity reserve required, representing around 350 MW, which would have been sufficient to compensate for the hydroelectric power losses experienced during the winters of 2015 and 2016.

The second phase of the programme offers the opportunity to broaden and deepen the sources of supply secured for the contingency reserve. For instance, previously untapped sources of distributed generation could be considered, along with a limited volume of demand response from large loads. In addition, the potential to increase the contribution from the existing Bishkek CHP plant, or from the proposed second Bishkek CHP plant if commissioned, could be explored. The likely additional time required to undertake this phase is reflected in the time frames proposed in the roadmap. Timely completion of the scenario-based methodology for assessing contingency reserve requirements measure, as proposed in the roadmap, would ensure that decisions around the volume and nature of the reserves procured through the second and third stages of the programme could be informed by robust analysis, which may result in more efficient, more flexible, more resilient, better located and more cost-effective outcomes.

In the longer term, the third stage of the contingency reserve programme could seek to further extend the potential national and regional sources of supply. For instance, opportunities to broaden and deepen the provision of domestically sourced reserves could be explored, including demand response. Similarly, opportunities to procure emergency operating reserves from regional power producers could be considered, especially if the proposed measure to strengthen regional management of power system security were to materialise within the time frame envisaged in the roadmap. In the interim, it is anticipated that the current ad hoc regional reserve-sharing arrangements could continue as required. Alternatively, consideration could be given to constructing new generating capacity dedicated for the contingency reserve, such as an appropriately sized open-cycle gas turbine, should such an option prove to be cost-effective and practical to deploy. The proposed second Bishkek CHP plant may be in service toward the end of the implementation period and could provide an effective alternative source of new generating capacity for the contingency reserve. Some of these options are likely to be relatively expensive, politically challenging to pursue and time-consuming to deliver, which is reflected in the longer development and implementation time frames proposed.

The demand-side measures proposed in the roadmap have the potential to improve existing rationing arrangements and to unlock a range of resources that can complement and reinforce traditional supply-side responses to sustained power system security events. For instance, the communications strategy measure has the potential to help harness considerable voluntary power savings during a power system emergency event, while the contractual mechanisms measure potentially provides a practical means for securing contingency reserves from non-traditional sources, such as distributed generators. Similarly, the scarcity pricing measure combined with the contractual mechanisms measure has the potential to create powerful financial incentives for large-scale consumers to offer timely and efficient volumes of demand response during sustained emergency events. Together, these measures also have the potential to substantially increase overall power system flexibility and resilience, which would help to improve the reliability of the power system, especially during a sustained hydrological event.

Similarly, energy efficiency and power consumption substitution measures have considerable potential to deliver substantial power savings in the longer term, which could significantly improve power system security over time. Accordingly, it is proposed that measures be developed and implemented to incrementally harness these power savings, initially focusing on improving building energy efficiency, and the deployment of more efficient space heating and appliances. Opportunities to switch from electric space heating to efficient alternatives, such as district heating, could also be pursued where it is feasible and cost-effective to do so. Initial priority should be given to harnessing these opportunities in the residential, industrial and public sectors.

However, in the shorter term, the most practical opportunities for timely and cost-effective deployment of energy efficiency and substitution measures in the lead-up to and during a sustained emergency event are likely to be limited to energy-efficient lighting, maintenance to improve electric motor efficiency, minor building weatherisation initiatives and some opportunistic substitution of space heating. A power saving education and awareness programme targeting the residential sector could also be considered as part of the immediate response, which could be developed as part of the proposed communications and media strategy measure.

Beyond the traditional forms of consumption rationing, several of the demand-side measures proposed are likely to be new to Kyrgyzstan and may take longer to develop and implement than some of the other better understood measures proposed. This is reflected in the longer lead times proposed for the development and implementation of those measures in the roadmap. It is also reflected in the proposed measure to develop an integrated deployment strategy to ensure that demand-side measures are available and ready to deploy during sustained emergency events. This measure has the potential to become a key catalyst for timely, efficient and effective deployment of demand-side measures. Hence, it is proposed to give high priority to its development and deployment.

This combination of measures provides an integrated and comprehensive approach for pursuing power system security in Kyrgyzstan. In particular, the proposed roadmap provides a range of practical measures focused on the key areas of power production and consumption that will determine power system reliability and resilience during a sustained hydrological event.

The roadmap also recognises the interrelated nature of the power system security challenges facing Kyrgyzstan during sustained periods of water shortage, and will support the development of a mutually reinforcing set of policies and programmes that can address these matters in a practical, timely and cost-effective manner. As a result, the proposed approach is likely to be durable and able to adapt to changing requirements over time.

Nevertheless, a range of practical and evolving risks and challenges are likely to be encountered as implementation and operational deployment proceed, which will require ongoing flexibility and adaptability to resolve. International experience suggests that the most effective way to respond to these challenges is to adopt an incremental and innovative approach to deployment, reflecting the principles of continual improvement.

Under this approach, policies are typically implemented in stages, initially involving demonstration projects or some other targeted activity, with the lessons drawn from experience fed into the next iteration of deployment. Policies are developed and refined gradually in a co-ordinated manner as these implementation cycles proceed. Increasing maturity can be expected to bring greater confidence and the wider stakeholder support needed to progressively deploy policies and programmes to a larger target group, increasing the measure's effectiveness while drawing on practical experience to reduce subsequent implementation risks and costs.

The government of the Kyrgyz Republic could therefore consider adopting this type of approach, supported by effective management and appropriate whole-of-government co-ordination, to ensure that the measures are developed and deployed in a timely and effective manner.

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