


Article

Mapping Potential for Improving Rural Energy Services in Kyrgyzstan: Factors for Achieving Sustainable Development Goals in the Community Context

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Abstract: Energy is a pivotal element for overall development. Therefore, affordable and clean energy for all (Sustainable Development Goal 7) is one of the important elements. Despite a suitable approach, Kyrgyzstan lags behind to achieve its Sustainable Development Goals by 2030. Improving access to energy can significantly impact the progress of many other sustainable development targets. However, access to reliable, sustainable, and adequate energy is a crucial task in rural Kyrgyzstan. Taking into consideration the energy situation and the importance of the availability of energy services, the overarching aim of the presented article is to map the potential of improving rural energy services to foster overall sustainable development goals. The article presents the most relevant information about rural energy usage behaviour based on three primary pillars: energy demand, energy carrier, and energy sources. In addition, the presented research article synthesises the key driving factors which have a direct or indirect impact on the energy services in rural areas. The summarised data displays a deep insight into a variety of complex and dynamic household energy consumption patterns. The article provides a potential solution nexus to foster improved energy services in rural Kyrgyzstan and therefore to foster the overall sustainable development in Kyrgyzstan. The findings of the article help to formulate a strategy to design rural energy services for policy makers and stockholders.

Keywords: energy need; rural livelihood; energy poverty; energy services; sustainable energy transition; sustainable development goals; Kyrgyzstan; Central Asia



Citation: Mehta, K.; Ehrenwirth, M.; Trinkl, C.; Zörner, W. Mapping Potential for Improving Rural Energy Services in Kyrgyzstan: Factors for Achieving Sustainable Development Goals in the Community Context. *World* **2022**, *3*, 586–606. <https://doi.org/10.3390/world3030032>

Academic Editor: Lassi Linnanen

Received: 12 June 2022

Accepted: 9 August 2022

Published: 16 August 2022

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1. Introduction

1.1. Setting the Stage

The objective of the Sustainable Development Goals (SDGs) serves as a blueprint to achieve a better and more sustainable future for all. SDGs include various social, economic, technical, and environmental aspects. Along with the other countries, Kyrgyzstan has committed to the achievement of the global SDGs [1]. Among the most critical challenges, energy-related challenges are the most crucial for Kyrgyzstan. Out of five countries in Central Asia, Kyrgyzstan is one of the most vulnerable countries to climate change. Over 60% of the rural Kyrgyz population is directly dependent on natural resources for their livelihoods [2,3].

Kyrgyzstan—a former Soviet Union country—was one of the countries significantly affected by the separation. The Tien Shan mountain range covers over 90% of the country's territory [4]. Therefore, Kyrgyzstan is well known for its high-altitude and mountainous characteristics. Naturally, the high-altitude characteristics and mountainous identity of Kyrgyzstan place the country in the cold climatic zone. Because of the country's geographical features, the energy need for domestic space heating is a key priority compared to the energy need for lighting and cooking in Kyrgyzstan [5].

Mehta et al. [2] extensively derived a comprehensive analysis of the energy situation in Kyrgyzstan (and other Central Asian countries). One can read the author's previous

work to understand the current energy challenges to the Kyrgyz energy sector as well as the effect of the breakdown of the Soviet Union on the contemporary Kyrgyz energy sector.

The literature review recognised that access to energy is crucial to improving livelihoods. As a result of the limited energy infrastructure and affordability, most rural people rely on solid fuels such as coal, wood, and cow dung to meet their primary energy needs [6]. The usage of non-sustainable solid fuels is not favourable for health and environmental dimensions. The overconsumption of non-sustainable solid fuels significantly contributes to producing indoor and outdoor air pollution [7]. Moreover, the available widespread forest cover (i.e., riparian forests) is often exploited to fulfil the energy needs of rural people. The burden on local forest cover for wood leads to a negative impact on the riparian forests in Kyrgyzstan [2,6–9]. Hence, energy is a defining and complex issue, and rural Kyrgyzstan experiences energy vulnerability where almost 70% of the Kyrgyz population resides [4,10,11].

1.2. Localizing Sustainable Development Goals in Kyrgyzstan

Based on the results of the SDG dashboard and available data from Sachs et al. [12], Figure 1 attempts to localize the SDG goals in the framework of Kyrgyzstan and summarize the progress until 2020. It can be observed that for the majority of the SDGs, minor/major challenges have remained. The current situation projects that it will be difficult to achieve SDGs by end of 2030 for the Kyrgyz Republic.

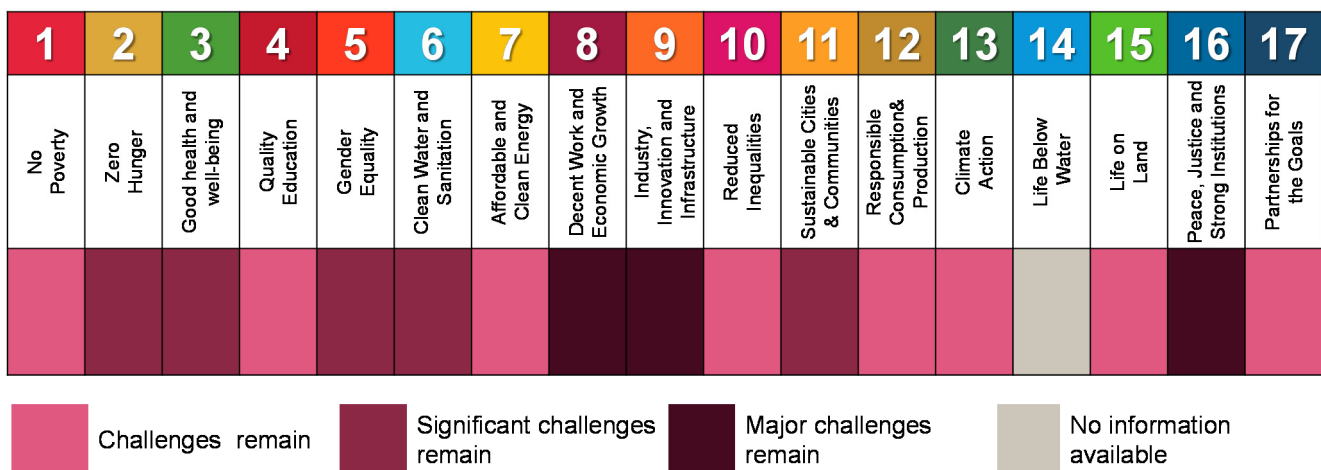


Figure 1. SDG dashboard in the context of Kyrgyzstan based on [12].

Some researchers have addressed that energy is a fundamental element in the development of all aspects of human livelihood, including access to water, agricultural productivity, health care, education, job creation, climate change, and environmental sustainability. Therefore, SDG 7 (affordable and clean energy) can be considered as one of the essential goals in the overall framework [13–15]. Achieving the goals of SDG 7 will significantly impact the progress of many other SDG targets [16]. McCollum et al. [17] mentioned that there is a strong interlink between the target of SDG 7 and other SDG dimensions. It was further explained how progress in SDG 7 can bring progress to other goals by presenting key interactions between various goals. In addition, Madurai Elavarasan et al. [18] envisioned the impact of SDG 7 on the United Nations SDGs in detail. Figure 2 represents the interaction of SDG 7 with other goals. For example, having access to energy creates job opportunities and boosts the economy.

With the increment of renewable energy, the necessary climate actions and the sustainable societies will immediately be interlinked and changed positively. Summing up, the research concluded that SDG 7 has a major communication impact chain on other SDG dimensions (especially environment-related goals). Therefore, it is important and crucial to foster SDG 7 progress for overall development [19].

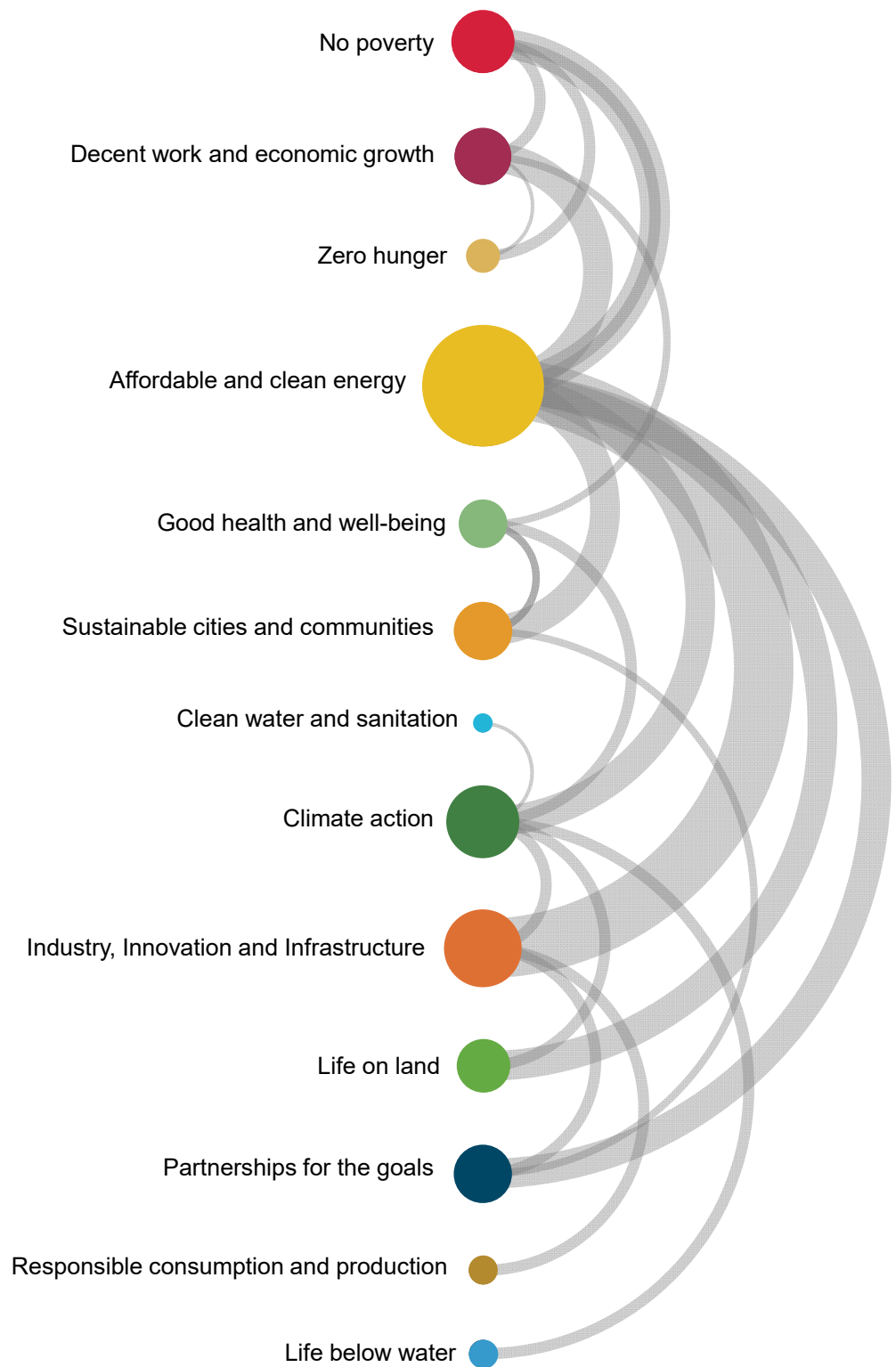


Figure 2. Visualizing the interlinkage of SDG 7 with other goals (own illustration based on [18]).

According to the progress report, SDG 7 is on track in the Kyrgyz Republic. Access to modern and sufficient energy services is a key factor to address the Sustainable Development Goals (Goal 7: Affordable and clean energy). The evaluation parameters for SDG 7 are listed below.

- Subgoal 7.1: By 2030, ensure universal access to affordable, reliable, and modern energy services.
- Subgoal 7.2: By 2030, increase substantially the share of renewable energy in the global energy mix.
- Subgoal 7.3: By 2030, double the global rate of improvement in energy efficiency.

Due to the Russian legacy, access to electrification is universal in the Kyrgyz Republic. However, due to outdated infrastructure, poor supply quality, and affordability for rural people, electricity is not used adequately, even though the households are connected. Similarly, due to the absence of modern energy services, rural communities use non-sustainable solid fuels to meet heating and cooking demand [2]. In addition to the abundant amount of natural/conventional resources, Kyrgyzstan has a great potential for various renewable energy sources (i.e., solar, wind, and biomass). However, available sustainable energy sources are not significantly employed for energy generation and are therefore mainly untapped in Kyrgyzstan [11]. Summing up, despite being on track, there are significant challenges that remain to achieve SDG 7 in Kyrgyzstan, especially since this is critical in the framework of rural Kyrgyzstan. Hence, there is a need to emphasize how to foster SDG 7 progress in rural areas of Kyrgyzstan.

To achieve SDG 7, energy transition is the first and foremost step [18]. Recent theoretical developments have identified that rural areas are crucial for the energy transition. Arguably, the energy transitions in the Global North have mainly focused on urban areas and metro cities [20]. However, in the majority of the developing countries, the population still resides in rural areas and does not have any benefits from progress and development [21]. Therefore, the strategy to design rural energy services has been limitedly used in scientific publications, especially in Central Asian countries [2,20,22]. As a result, there is no evidence available about how to conceptualize the potential to improve the rural energy transition for Kyrgyzstan which is one of the most urgent issues to be addressed.

1.3. Visualizing the Gap in the Research and Research Objectives

To outline and justify the research gap, a bibliometric analysis was performed by collecting all the relevant papers published in Scopus (ScienceDirect database) [23]. To retrieve the data, energy-related terminologies/keywords were used, such as energy services, energy poverty, energy security, energy, energy in rural areas, water-energy nexus, fuel poverty, energy need, energy policy, energy issue, energy consumption, etc., in the context of Kyrgyzstan with the Boolean operator AND. The search was applied in both the title and abstract in the English language to find the most weighted research related to energy in Kyrgyzstan. To be more specific, the publications were selected from the time series 1991 (after Kyrgyzstan's independence) until today. The inquiry yielded more than 500 articles from the Scopus database. The bibliometric assessment of the collected articles is represented in Figure 3, which abstracts the most important and repetitive keywords in the field of energy research in Kyrgyzstan. To portray the network structure of the similarity matrix, the VOS viewer was used. The VOS viewer is a bibliographic assessment tool developed by Nees Jan van Eck and Ludo Waltman that is utilised to display and visualize co-occurrence relationships in the literature [24].

The bibliometric analysis of the energy-related articles identified that the common research with a focus on the field of Kyrgyzstan remains limited to the selective research field. The trending research mainly focuses on energy trade between neighbouring countries, climate change, water-energy conflicts and challenges, energy, agriculture, laws, regulations, economics, and border-related focuses. It can be seen from Figure 3 that there are very limited keywords/research available for energy research that focused on rural areas and rural energy services. In addition, Mehta et al. [2] mentioned that energy-related research is relatively inadequate for rural Kyrgyzstan/Central Asia. The scant information available does not allow us to plan rural energy services. To foster SDG 7 development in rural Kyrgyzstan, such scientific knowledge is mandatory.

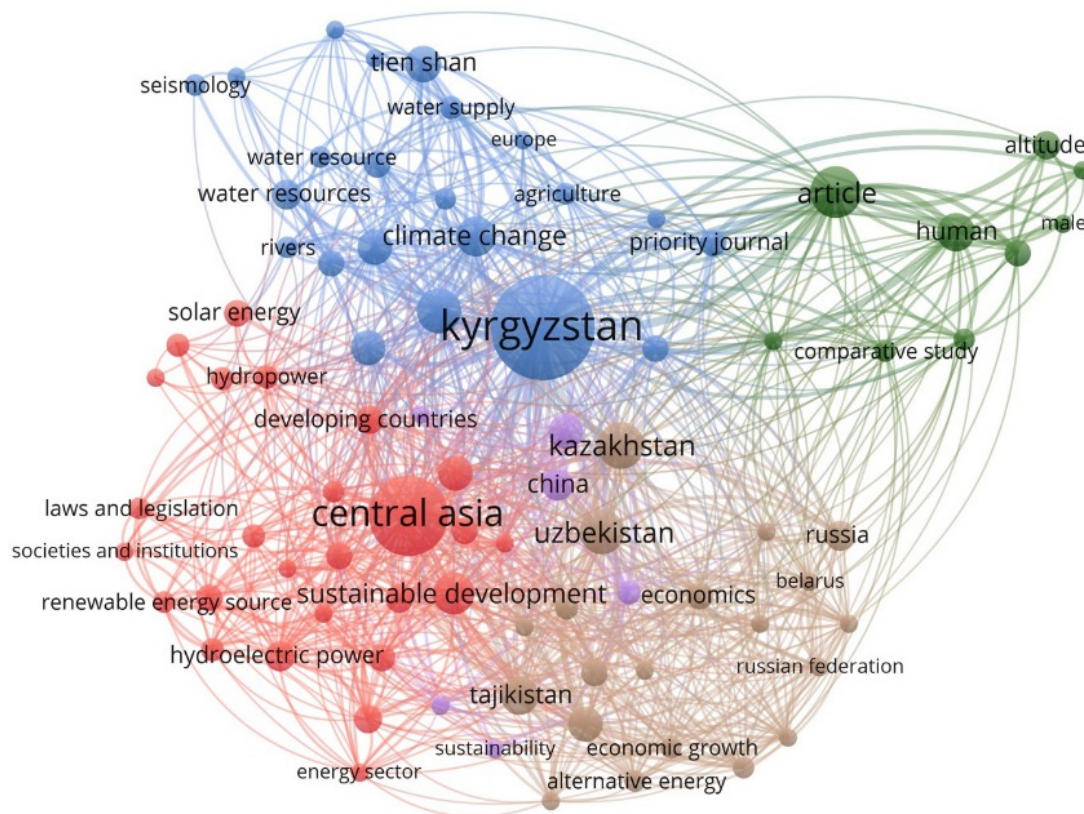


Figure 3. The bibliometric analysis of the most relevant keywords in the field of energy research in rural Kyrgyzstan.

Hence, there is a need to outline the status-quo of the household energy consumption pattern. This will allow an understanding of the basic energy needs of rural Kyrgyzstan. However, as mentioned, a knowledge gap exists related to the energy identity of rural Kyrgyzstan. The limited available research does not provide a detailed overview of the special and unique energy behaviour of rural livelihoods for international readers.

To fill the knowledge gaps in the field and offer novel information to the scientific community, the presented article attempts to develop household energy consumption patterns that describe the energy behaviour of rural Kyrgyzstan. In addition, it identifies the relevance of how to foster sustainable development through increasing rural energy services. Therefore, the main objectives of this study were as follows:

- Map the energy landscape of rural Kyrgyzstan based on the author's on-site visit, literature review, and statistical data.
- Derivation of key driving factors which have an impact (direct or indirect) on the energy services in rural areas.
- Identification of a potential solution nexus to foster energy services in rural Kyrgyzstan.

The necessary information was collected from the author's on-site household visit and interviews with local rural Kyrgyz people Ak-Tal, Emgek-Talaa, and Tash-Bashat, a literature review, and statistical data.

2. Research Methodology

The research paper starts by analyzing and narrating the energy situation in rural Kyrgyzstan and the overall livelihood challenges faced as a result to poor energy conditions based mainly on the author's on-site visits and perspective. Based on further literature review and statistical data, the paper also establishes Kyrgyzstan's overall standing on each SDG. Therefore, to meet the main objectives of the presented article, the paper then focuses on localizing SDGs for Kyrgyzstan and outlines how SDG 7 is one of the important goals

for the overall development. This establishes an understanding of the importance of rural energy services in Kyrgyzstan.

The article then presents the most relevant set of information about rural energy usage behaviour based on three primary pillars: energy demand (heating, electricity, and hot water preparation), energy carrier (usable energy form), and energy sources (primary energy) to cover the overall aspect of the energy situation (demand and supply). The author had a close look at the energy usage pattern of rural Kyrgyz households. Various questions were asked through the pilot interviews regarding energy use, energy expenditure, energy usage behaviour, daily routines, building conditions, and willingness to adopt renewable energy. As mentioned previously, the households were chosen from the typical rural Kyrgyz community (i.e., Ak-Tal, Emgek-Talaa, and Tash-Bashat). That information adds novelty to the research article. It addresses the knowledge gap that exists regarding rural energy outlook as opposed to the existing information on urban and metro cities. The novel information was blended with the recent literature review to add supplementary information to display the energy outlook of Kyrgyzstan through the three pillars mentioned above. After the energy status quo, the presented article describes the driving factors which influence energy demand and supply in rural Kyrgyzstan. In addition to the energy pattern, the presented research article highlights the catalogue of driving forces and how it affects the overall energy identity in rural areas.

Finally, the pathway and future scope for sustainable energy transition in rural Kyrgyzstan are recapitulated. The article provides a detailed explanation and inter-connection between the various driving factors on the energy services in rural Kyrgyzstan. The supplementary data was collected from various journal articles, conference proceedings, reports, and books based on energy-related keywords as mentioned above. Figure 4 represents the methodology of the presented article.

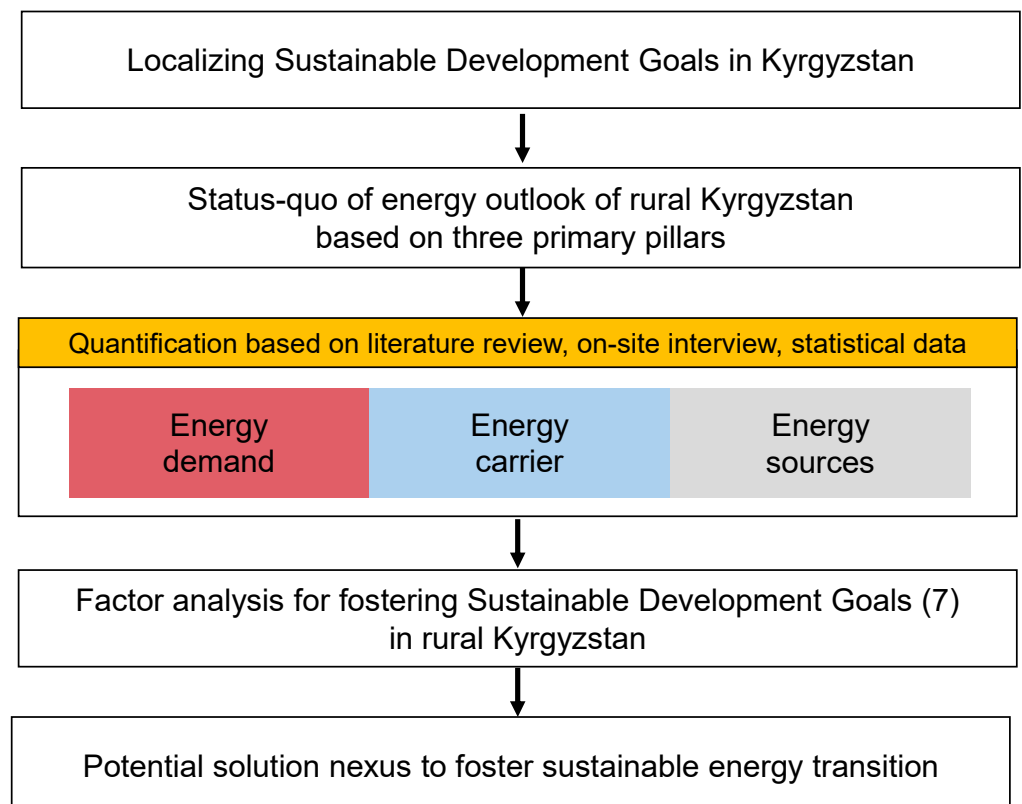


Figure 4. Research methodology of the presented article.

3. Energy Outlook of Rural Kyrgyzstan

3.1. Energy Demand

Due to the mountainous nature of the Kyrgyz territory, the Kyrgyz weather is influenced by the mountain ranges and its continental location. The cold climate results in long heating seasons which last 6 to 9 months in the Kyrgyz Republic. In that case, access to a reliable and sufficient heat supply for house heating is a primary need for Kyrgyz citizens [25]. The heating need is even more critical at high altitudes where most of the rural settlements are located. The winters are extended because of the high-altitude characteristics in such regions. Hence, maintaining thermal comfort in rural homes is a key and primary need. The majority of the Kyrgyz building stock (more than 50%) was constructed during the Soviet period roughly 35–60 years ago with earthen materials without insulation. Such conditions of building stocks result in high heat demand and low thermal comfort [26]. Figure 5 displays the annual space-heating demand according to various construction types.

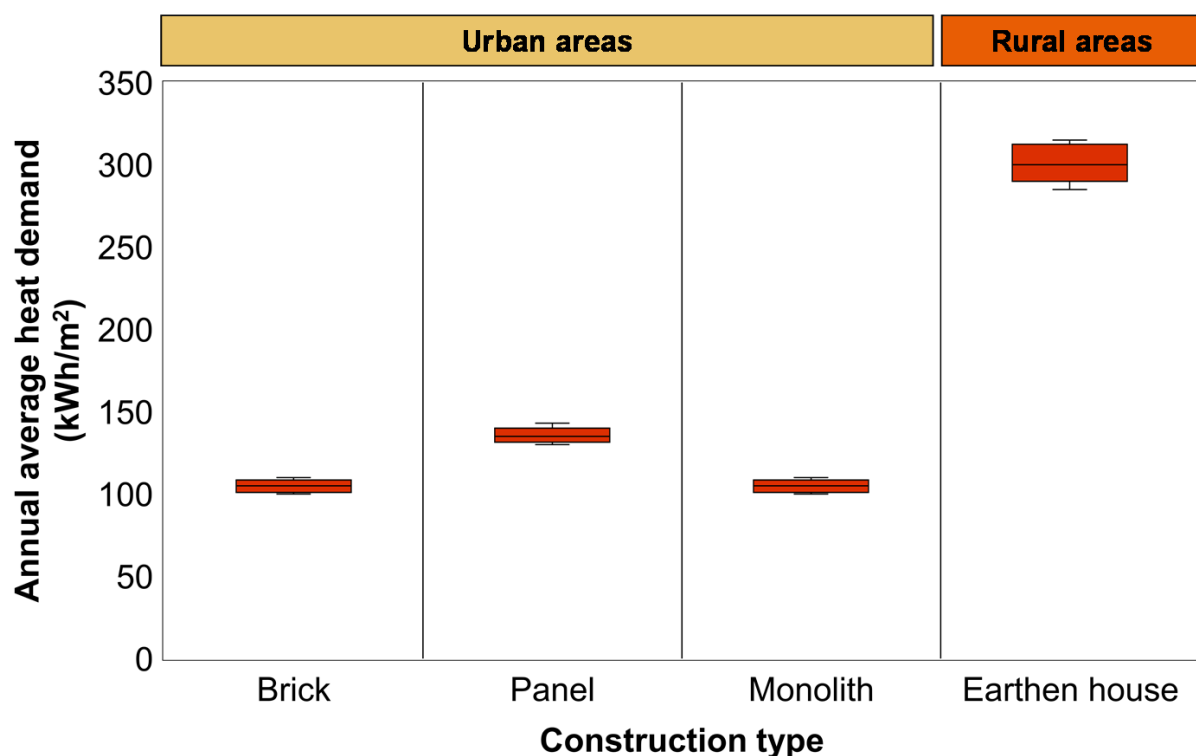


Figure 5. Space-heating demand in Kyrgyzstan characterized by urban and rural areas [own illustration based on Balabanyan et al. [25].

Moreover, the mountainous characteristics result in abundant water resources and are calculated as 3900 MW of total installed hydropower capacity. The Naryn River is a key water channel, which rises in the Tien Shan Mountains and flows across Kyrgyzstan and downstream countries [27]. The huge hydro resources are responsible for the production of around 93% of total power with different small hydropower plants in Kyrgyzstan (the rest of the power is generated with the thermal power stations). Thus, hydropower plants have the largest share in the country's electricity generation framework. In addition, because of the legacy of Soviet infrastructure, access to electricity through the national grid is common in Kyrgyzstan, covering 99.8% of rural and urban households [28,29].

The available water resources in Kyrgyzstan are generally used for two purposes. The first purpose is to produce hydroelectric power, and the second purpose is to release the water to downstream countries for agricultural activities. Because of the extremely cold winters, the energy production from hydropower fluctuates (due to reduced water flow), which has a major effect on power supply consistency. As a result of the high thermal

energy prices and low-electricity tariff, a substantial urban Kyrgyz population practices individual electric-based heating solutions to maintain thermal comfort inside houses during winter [3]. Hence, more electricity is required, and at the same time, the power production is reduced due to the reduced water flow. Therefore, there is a significant seasonal demand gap between summer and winter [28,30].

Because of the urbanisation and high population density, supply priority is given to urban areas to meet the increased electricity demand during winter. Because of the isolated locations and low-population density, rural areas are left out of the reliable electricity supply. It was reported that high-altitude mountainous rural houses frequently (i.e., every week) experience electricity interruptions. Hence, the rural population uses limited electricity and is more inclined towards traditional fuels for covering their energy needs. The seasonal electricity need is mentioned in Figure 6 for urban and rural areas. To meet the winter demand, electricity is generally imported from neighbouring countries.

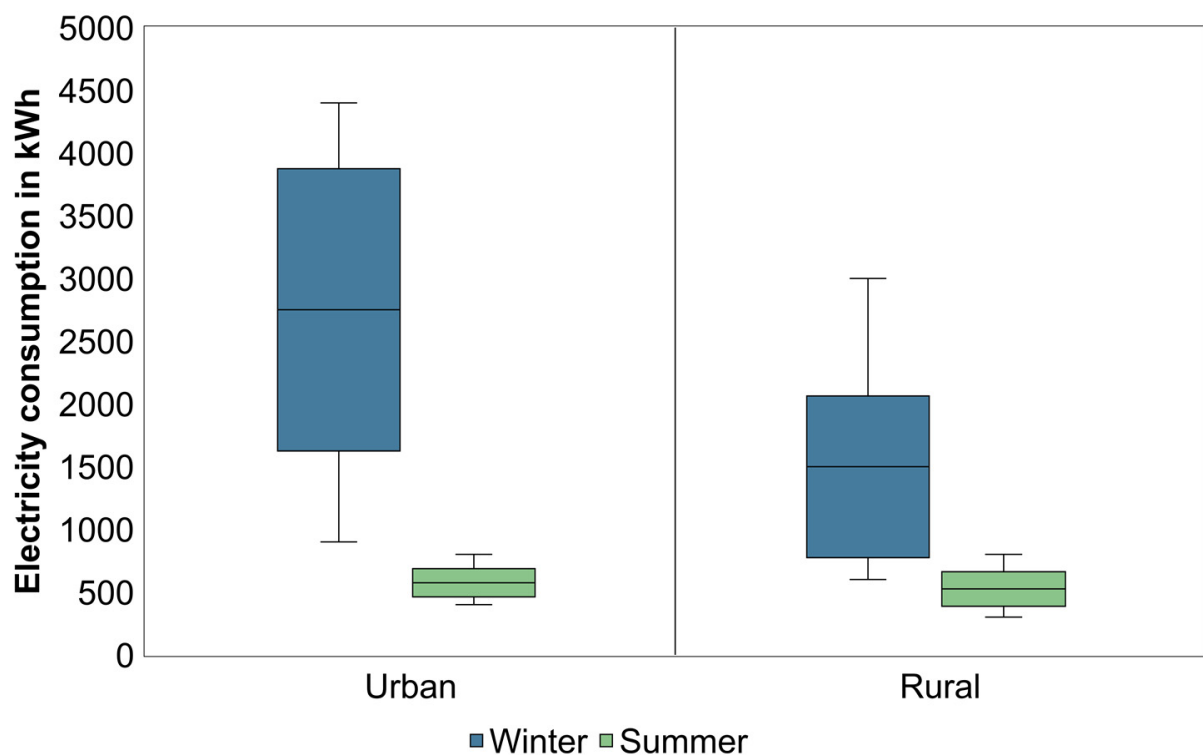


Figure 6. Seasonal residential electricity consumption in Kyrgyzstan [own illustration based on MEI [31].

Notwithstanding low energy tariffs, rural households in mountain Kyrgyzstan experience difficulties in meeting winter energy needs. Most of the rural households are not connected to the central water supply system because of the isolated location of the rural settlements (because of the limited infrastructure). Hence, most of rural homes do not have domestic hydraulics inside their homes which limits hot water use. Instead, traditional heating stoves prepare domestic hot water. To save heating fuels and money on hot water preparation, rural Kyrgyz families used to limit hot water consumption to between 20–50 L per day. In contrast, daily hot water consumption per household in Bishkek is around 100 L [32]. In Kyrgyzstan, natural gas and electricity (as they have access to electricity) are the main sources for cooking at home. High-income rural families can afford to use electricity, while low-income rural houses prefer to use traditional heating stoves with electric stoves for cooking. Figure 7a represents the typical traditional stove (used for heating, hot water preparation, and cooking), and Figure 7b represents the electric stove used for cooking.

According to the local geographical and topographical conditions, it can be comprehended that heating is the primary need for the Kyrgyz people. As domestic space heating is a key primary need, there is very limited and accurate energy information (supply and consumption) available about domestic hot water and domestic cooking in rural areas. In summary, with the growing population, the demand for heat and electricity is increasing, but at the same time, the energy infrastructure of the Kyrgyz power and heating sectors is inefficient, which results in high energy losses.



(a)



(b)

Figure 7. (a) Traditional stove used for heating, hot water preparation, and cooking; (b) electric induction stove for cooking and electric kettle for hot water preparation.

3.2. Energy Sources

The majority of the energy demand of Kyrgyzstan is met by local resources such as coal, natural gas, oil, and hydroelectric power. Because of the domestic coal mines, coal is the widespread and common solid fuel used in urban and rural Kyrgyzstan. To meet the primary need for heating, various options are available, starting from the individual heating solution (traditional heating stove), household boiler, and radiators as well as a district heating (DH) system. The DH networks are thoroughly integrated into the capital city (Bishkek) and neighbouring urban areas. The remaining population in (other urban areas and rural areas) relies heavily on solid fuels for heating [33].

Most of the rural population is engaged in agricultural and forestry activities, which are mainly stopped in winter (minimum of six months) [32]. Consequently, this is one of the reasons for a low-income scenario in rural areas. Moreover, when energy needs are particularly acute (in winter), because of the strained power network, rural households experience persistent blackouts. Hence, despite the low-electricity tariff, an electric-assisted heating solution is neither affordable nor reliable for the rural population. In this context, house heating with the traditional heating stoves (fuelled by non-sustainable solid fuels) is the most usual practice in rural Kyrgyzstan.

Certainly, because of high incomes and upgraded living standards, electricity is accepted as a secondary heating supply in urban areas. In contrast, rural households practice individual heating solutions by fuelling various heating fuel mixtures according to their financial situations. Figure 8 presents the energy (heat) supply pattern in the capital (Bishkek) and in urban and rural areas. It explains the proportion of the fuel combined with the main fuel source for space heating (coal, electricity, and wood) according to location.

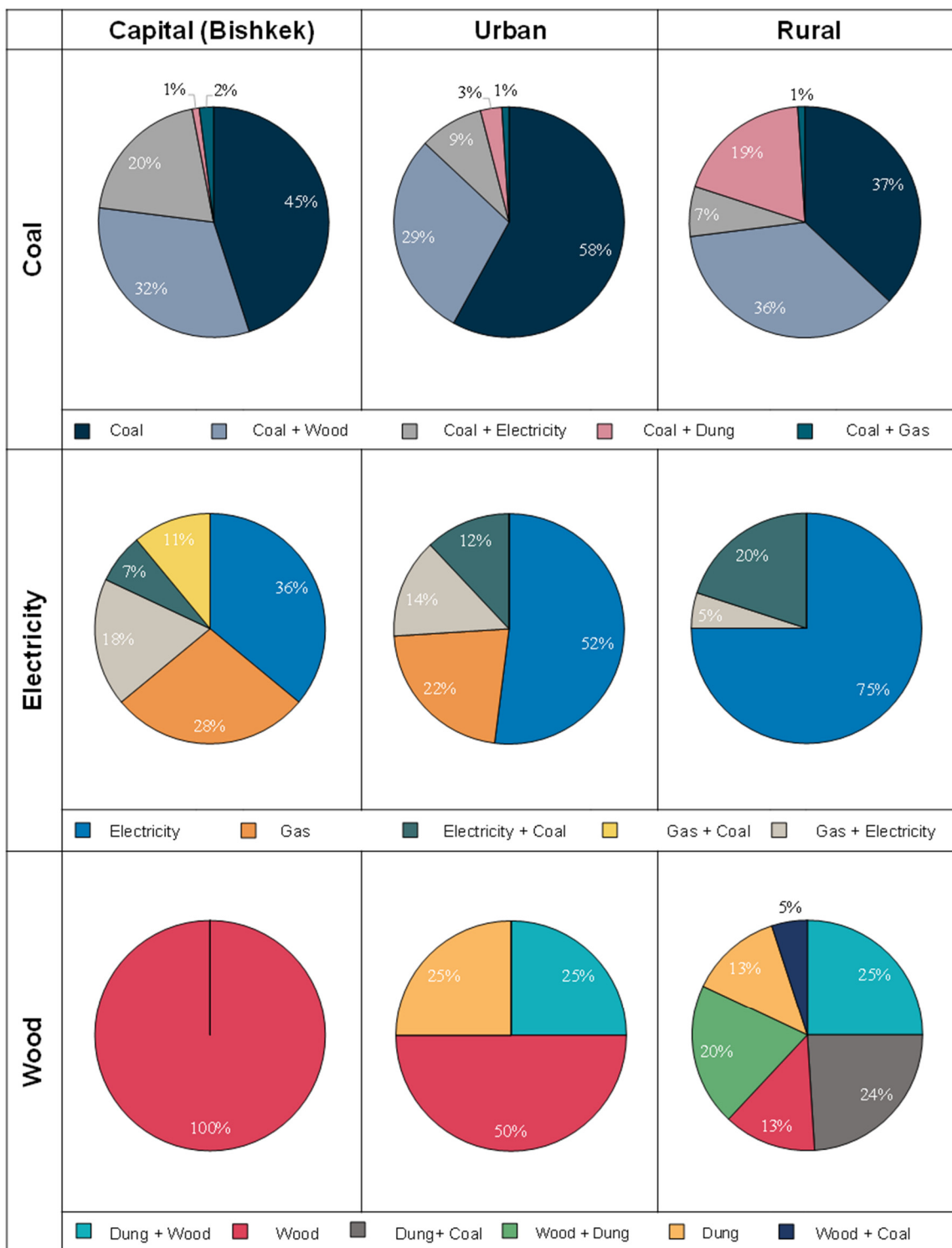


Figure 8. Representation of heating fuel mixture/combination (heating fuels with the key energy source (coal, electricity, and wood)) for domestic space heating according to the region [own illustration based on World Bank [33].

Close to 80% of rural households intensively use non-sustainable solid fuels to operate traditional heating stoves for house heating [33]. During winter, the energy supply for cooking and hot water is generally assisted by space-heating stoves in rural areas. Figure 9 displays how heating stoves are used to meet the energy need for hot water and cooking according to region.

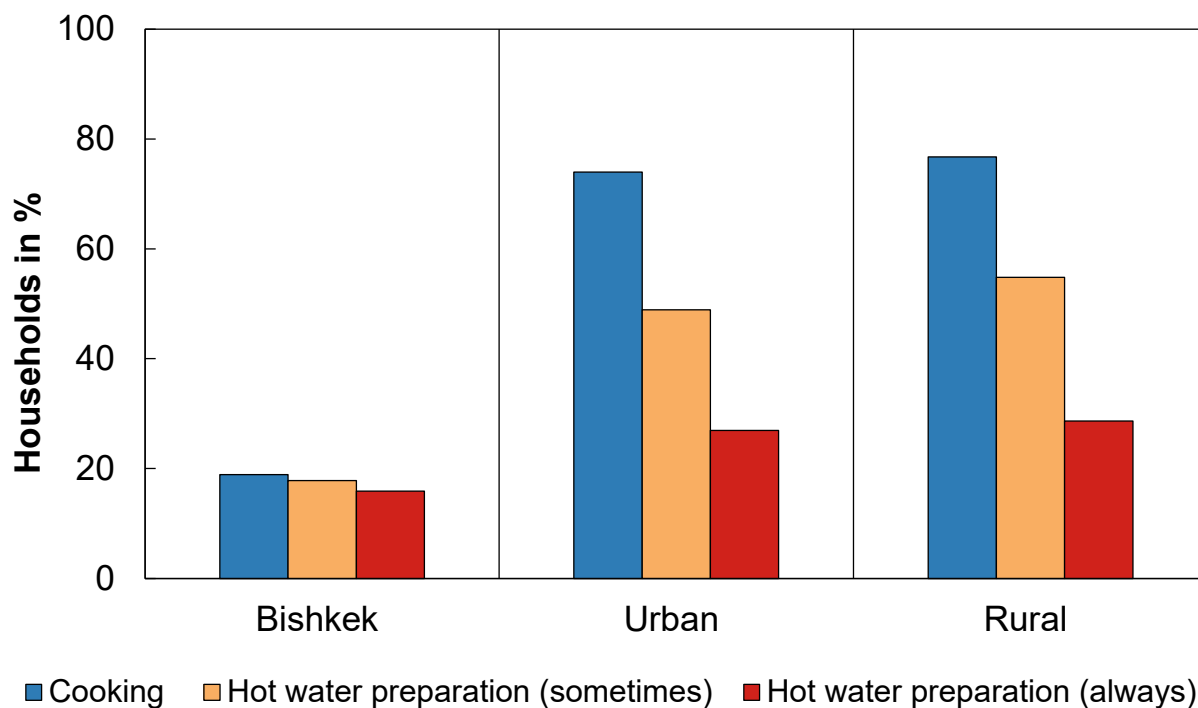


Figure 9. Cooking and hot water preparation on the traditional heating stove [own illustration based on World Bank [33].

In addition to the affordability issue, the modern energy services available in Kyrgyzstan have their own limitations/constraints, which are described in Table 1.

Table 1. Comparative assessment of modern energy supply available in Kyrgyzstan [own interpretation based on Balabanyan et al. [25]; World Bank [33].

Electricity	District Heating	Natural Gas and Others
<ul style="list-style-type: none"> • Strained network • Dependent on season • Old infrastructure • Transmission losses 	<ul style="list-style-type: none"> • Limited connectivity • Network heat losses • Old structure • Unmet heat demand 	<ul style="list-style-type: none"> • Limited availability • Limited gasification • Financial barrier • Limited availability

3.3. Energy Carrier/Usable Energy Form

The extended heating period and poor housing conditions are the responsible factors for high heating fuel consumption to maintain thermal comfort inside village homes. To reduce the heating fuel expenditure, rural households are used to occupying only one room for heating and closing down the rest of the house. Due to this situation, indoor air pollution is increased and responsible for health issues [25].

However, the energy sources and their consumption vary according to the building structure, region, and income level of households. The high-income families have a low-pressure boiler with higher thermal efficiency than traditional heating stoves. In that case, the required fuel for house heating can be reduced. Sometimes, according to financial capabilities, a few households prefer to (partially) use the electric radiator in combination with other traditional fuel sources.

Mehta et al. [2] derived a generalised impression about heating fuel consumption in rural areas. "It was identified that during the winter period (from October to March), based on the availability of heating fuels and financial capabilities, the average rural family needs to use 2 to 4 tons of coal, 1.5 to 3 m³ of firewood, and 1 to 2 truckloads of cow dung to

maintain thermal comfort in the house.” It was also assessed that coal and non-sustainable firewood are the favourite heating fuels to maintain thermal comfort in the house. People who live closer to the forest collect firewood themselves and use it for house heating. The coal is directly delivered to villages by trucks, where villagers can buy it according to their needs and can pay directly for it. Many rural households also use self-prepared manure cakes. The lower heating values and strong smell during burning make its utility limited as a heating fuel. However, households prefer to use self-prepared manure cakes for initialising heating. Mehta et al. [3] derived the energy pattern which is demonstrated by three pillars in Figure 10.

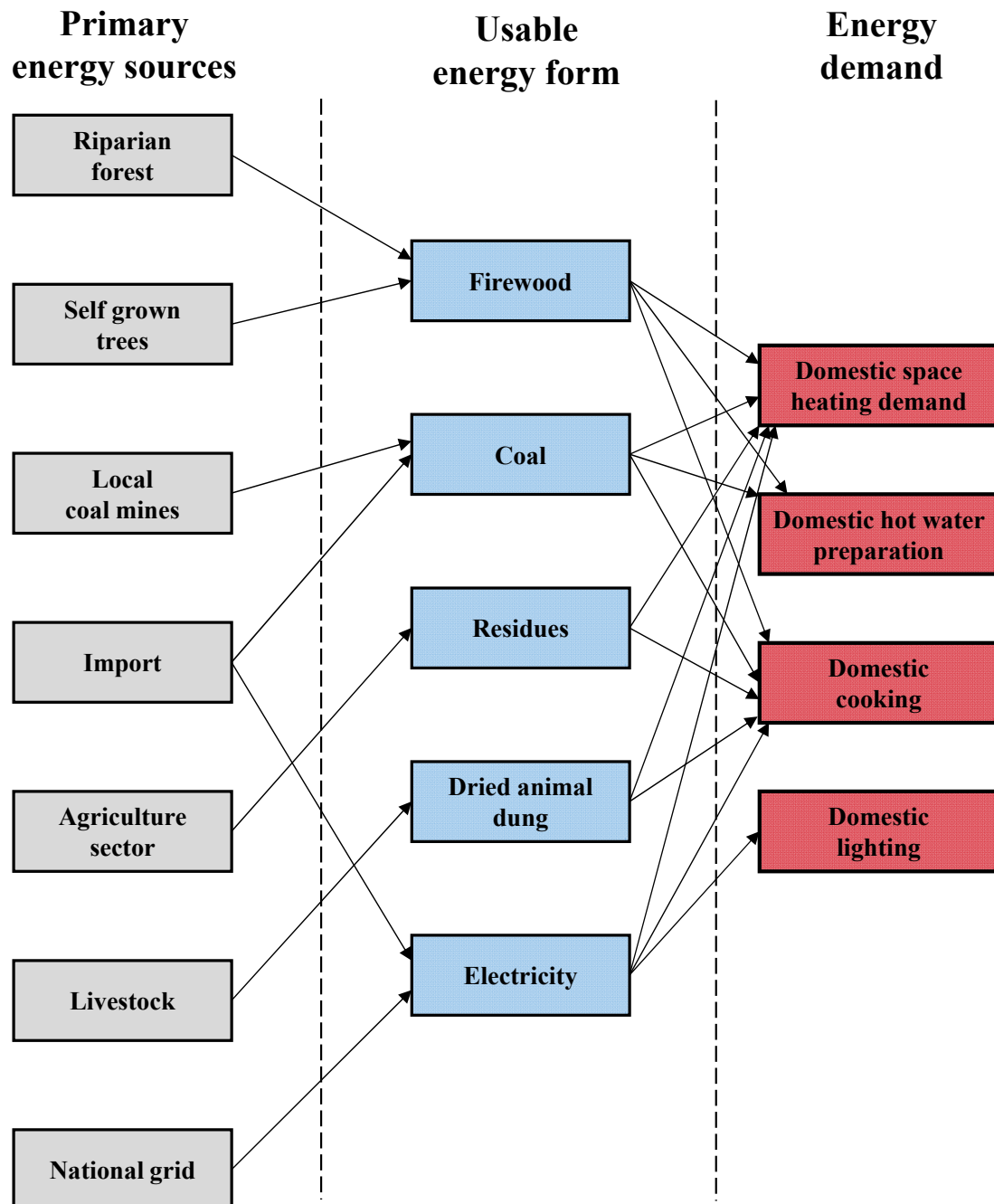


Figure 10. Energy supply and consumption pattern in rural Kyrgyzstan (based on Mehta et al. [3]).

The energy supply and consumption pattern presented in Figure 10 clarifies the catalogue of the energy behaviour of rural Kyrgyzstan. It can be seen from the energy

pattern that the block “energy demand” has a dynamic behaviour that can be influenced by certain parameters. The primary energy resources belong mostly to natural resources. It can be seen that most of the energy is derived from natural primary energy resources. However, the addition of sustainable energy resources in the supply chain potentially reduces the reliance on natural energy resources and the surrounding environment. In this context, it is essential to understand the driving factors behind the household energy consumption pattern and energy services in rural Kyrgyzstan.

4. Factor Analysis for Improving Rural Energy Services

The previous sections have provided the background and detailed information required to realize the complexity associated with the energy poverty of high-altitude rural communities. The synthesised information portrayed in Figure 11 showcases the inter-linked and complex energy situation of high-altitude rural Kyrgyz communities.

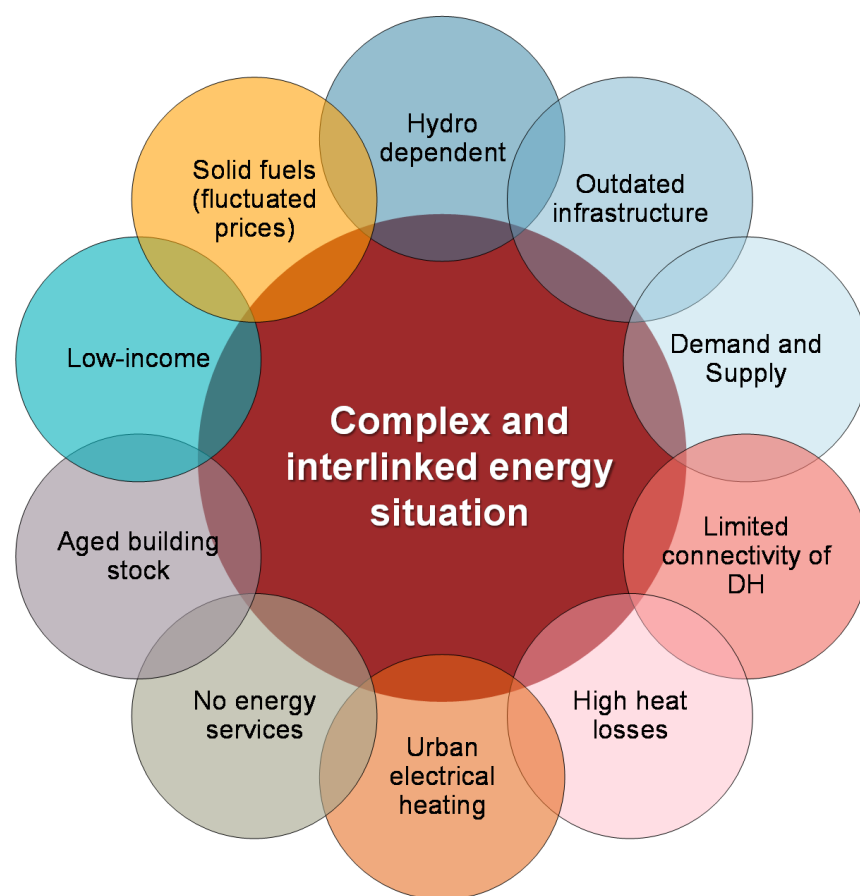


Figure 11. Illustration of the complex energy situation in Kyrgyzstan.

The aforementioned energy landscape of rural Kyrgyzstan helps explain that the rural population faces a complex energy structure to meet the primary energy needs. Energy vulnerability is widespread in rural areas because of the unequal distribution of energy services between urban and rural areas. However, Kyrgyzstan is endowed with abundant conventional and non-conventional resources, which can potentially bridge the gap between demand and supply and enhance livelihoods, especially in rural areas. The very limited/inadequate energy-related analysis is a significant barrier to decoding the complex energy structure. This chapter identifies external and internal factors which are directly and indirectly linked with the access to energy services in rural areas. Figure 12 highlights the selected geographical datasets, presenting basic yet important factors, which help understand the local boundary conditions easily.

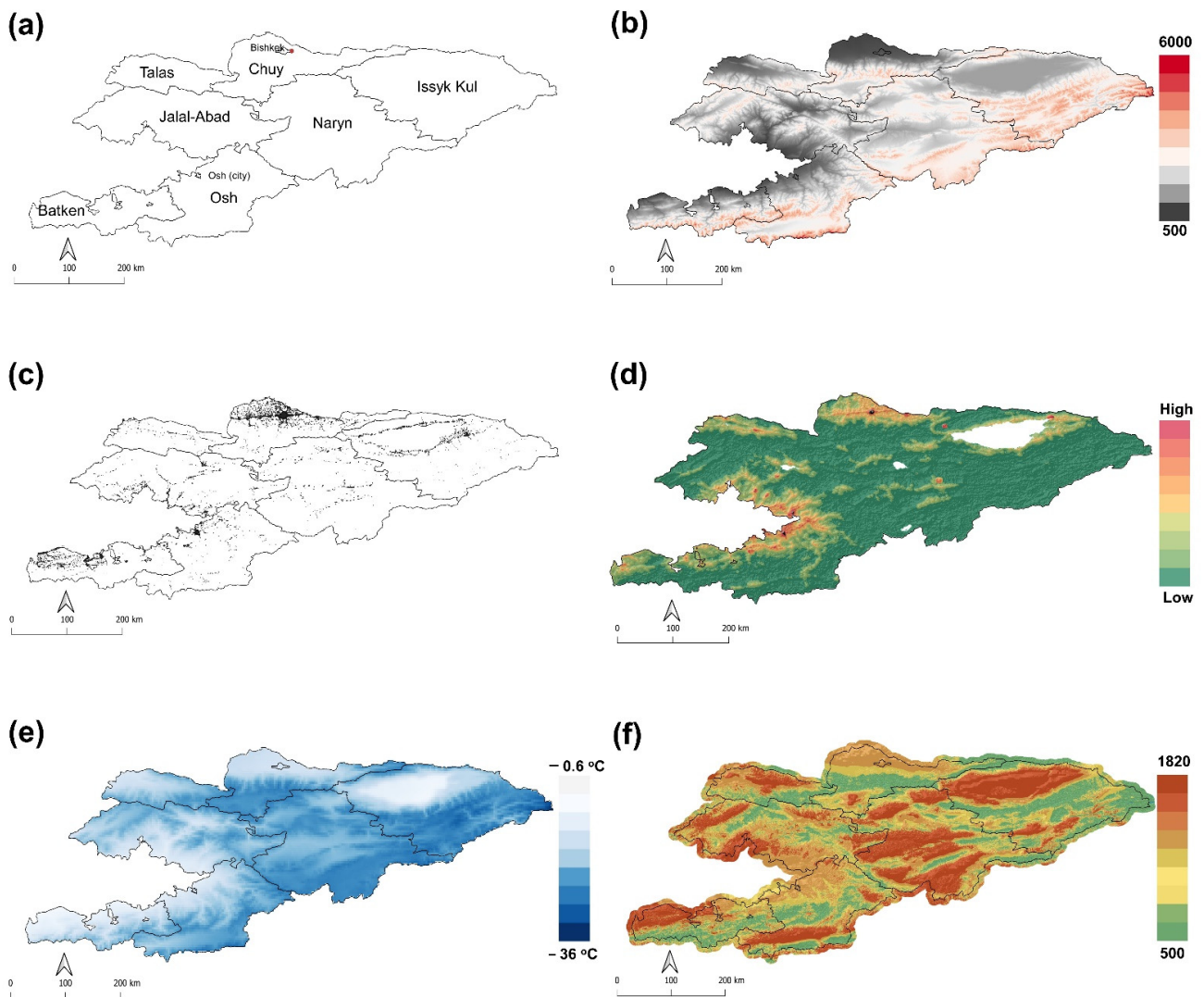


Figure 12. The selective geographical datasets for Kyrgyzstan: (a) administrative map [34]; (b) elevation in meters above sea level [35]; (c) building footprint [34]; (d) population density [34]; (e) average minimum temperature in 2018 [36]; and (f) global horizontal solar irradiation in kWh/m²/year [37].

There are various ways to project the determinants of the driving factors. However, in rural Kyrgyzstan, the energy pattern, such as employment of energy efficiency parameters, building renovation, switching from solid fuels to modern energy services, etc., is mostly decided by individual households (i.e., independent decision making). At the same time, several factors influence the energy externally because of the spatial geographical factors (elevation, climate, and location) and a variety of socio-economic features (energy policy framework, migration, urbanisation).

In conclusion, internal and external factors have a high impact on both the exploitation of sustainable energy in rural Kyrgyzstan and the enhancement of the energy pattern. Based on the literature study and the local boundary conditions, the presented article attempts to articulate the key driving factors (internal and external) which are listed in Figure 13.

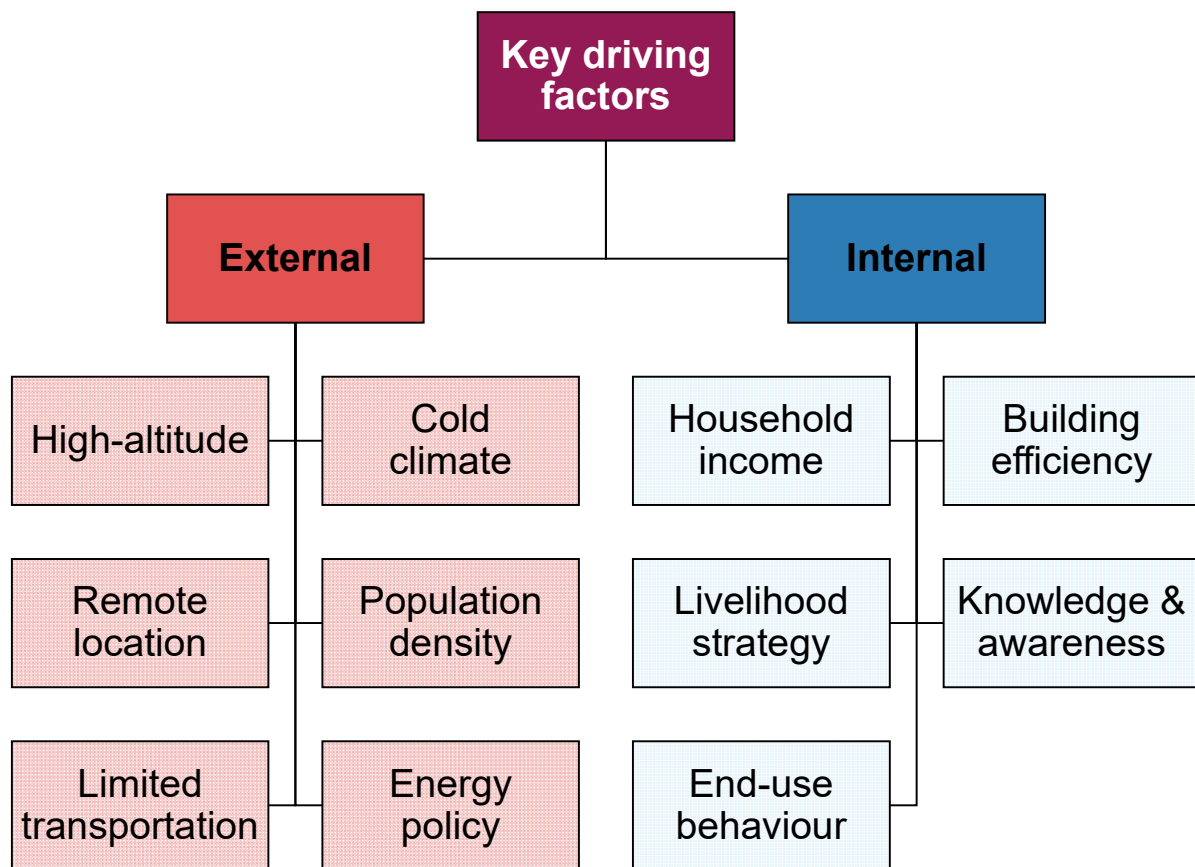


Figure 13. Derivation of the external and internal driving factors from the literature review.

External–Internal Driving Factors

Altitude and location are the two most prominent factors in rural Kyrgyzstan which can be correlated to the behaviour of total energy consumption [28]. By referring to Figure 12b, it is quite evident that the majority of Kyrgyz territory, around 95%, is located at altitudes above 1000 m and almost 40% is higher than 3000 m above sea level, which results in varying energy supply and consumption behaviour [4]. For example, in high-altitude rural Kyrgyzstan, the use of energy for space heating is higher compared to the lowland areas.

In general, the rural areas/settlements are located in remote high-altitude areas with a low population density, with a range of between 6 to 31 people per square kilometre which varies across different regions. For example, Naryn, one of the highest altitude and coldest regions in the country only has a population density of six people per square kilometre [4], whilst Chui and Osh belonging to low altitude regions have more inhabitants comparatively than other regions. Despite a smaller geographic perspective, the population density is high because of the most promising economic activities and migration. On the other hand, remote and high-altitude regions lead to the isolation of rural areas [6,38]. The connection between rural settlements and the main energy production centres in urban areas is affected due to geographical isolation and high-altitude terrain both of which are barriers to transportation activities that affect the supply and consumption pattern in rural areas [2].

Domestic space heating ranks as a priority amongst all the energy needs in high-altitude regions as the cold climate is prevalent throughout Kyrgyzstan. The temperature range during winter is about $-4\text{ }^{\circ}\text{C}$ to $-6\text{ }^{\circ}\text{C}$ (extremely cold winters) and even lower than $-30\text{ }^{\circ}\text{C}$ in mountainous valleys [33]. The cold climate is an external factor that influences the demand for energy in Kyrgyzstan. In contrast, low energy efficiency in the building

stock aggravates the energy demand in rural Kyrgyzstan. The growth of urbanisation has resulted in urban buildings complying with modern infrastructure standards (medium and/or high energy efficiency), providing access to communal services (i.e., DH, water supply) and are situated as dense areas. While the rural communities possessing low population density are characterised by scattered buildings which can be visualized by the building footprints plotted in Figure 12d. Due to the infrastructure development and the supply of energy, the low density and scattered rural settlements are often considered a low priority.

Furthermore, in the absence of modern construction facilities, the people of rural areas still reside in the earthen buildings without insulation that were built during the Soviet era. In urban Kyrgyzstan, because of the infrastructure development, the quality of new housing stock has been improving gradually [25]. In contrast, the qualities of building in rural areas remain the same (earthen houses/vernacular architecture). As mentioned previously, the high heat demand is usually fulfilled by the traditional stoves which are inefficient and are the key contributors to household air pollution. However, the limited source of income does not allow people to implement energy efficiency measures in their houses to reduce the high heat demand [39,40].

The population living in villages has a major dependency on the agricultural sector for their livelihood [6,39]. A consistent source of income is difficult to generate from agriculture activities as this occupation is reliant on weather conditions, and in most cases, there are vulnerable environmental changes. There is less revenue earned by the local farmers as the cold weather frequently hampers agricultural production. This creates an affordability limit for energy expenses [32]. This leads to a high dependency on non-sustainable solid fuels.

The selection of energy sources to meet household energy needs is influenced by energy price. For example, local biomass resources are easily available, but commercial energies are costlier for rural households. Due to the low rural incomes, when selecting energy sources, cost plays a crucial role. Naturally, the household energy consumption pattern is inspired by the development of the legislative framework about energy costs. The previous literature identified that the higher the energy price/cost, the lower the acceptance among the rural people [28,41]. This can be an indicator for the policy makers that the incentives for sustainable energy help encourage the rural population to use the new energy and become enablers for the energy transition in rural Kyrgyzstan. The costs of low energy and other incentive mechanisms encourage rural residents to change from traditional to sustainable energy sources [10].

Some of the vital factors that affect household energy consumption are family energy behaviour (decision making about the selection of the energy sources), livelihood strategy, and knowledge. Moreover, taking into account the local circumstances, the rural families, due to their low income, tend to use low-cost energy sources; that is, they use non-commercial energy sources [33]. Low-income families can lower other expenses to save the money needed for fuel expenditures. At the same time, the rural buildings which are old and uninsulated require high energy consumption due to the cold climate. Nevertheless, low-income rural groups face thermal discomfort inside their homes. Some rural residents only partially heat their homes during the heating season to reduce energy expenditure. On the other hand, high-income rural families prefer using commercial energy sources (i.e., an electric-based heating system in combination with the traditional heating stove) [33]. This creates a proportional correlation between user behaviour and a livelihood strategy. In addition to the livelihood and behaviour approach, awareness and knowledge also impact user behaviour and the adoption of modern energy services.

The aforementioned factors have a significant impact directly or indirectly on energy demand, energy consumption, and energy supply. Moreover, it can be observed how the driving factors are interlinked. Concerning the rural settlements in Kyrgyzstan for determining the driving factors of energy choice, it is critically significant to outline and project the energy transition process. Thus, a methodical explanation of the driving factors

would serve as a valuable outcome that offers the fundamental linkage between rural livelihoods and the provision of modern energy services.

To integrate sustainable energy in rural areas and to reduce solid fuel use, it is essential to have a deep insight into the driving factors that influence energy characteristics in rural Kyrgyzstan. The provision of energy services is a key feature influencing household energy consumption pattern in rural provinces of Kyrgyzstan. For example, non-sustainable woods are easily accessible with almost no or low cost in rural areas, while commercial energy sources are available in urban as well as lowland areas. The absence of modern energy services is mainly responsible for the diversified and complex household energy consumption pattern.

5. Solution Nexus to Improve Rural Energy Services

In addition to the abundant amount of natural/conventional resources, Kyrgyzstan is blessed with the great potential of renewable energy resources. This section attempts to present the thematic solution nexus to improve rural energy services in Kyrgyzstan. Given the presented various drivers and the resulting local situation, rural Kyrgyzstan is vulnerable regarding its energy services and continuously relies on natural resources to meet its energy need. However, the exploitation of renewable energy on a community level potentially helps to resolve the challenge in rural areas. As rural areas are characterised by low population densities, it is favourable to assess the energy planning and solution on the community level. In the end, to enhance rural livelihoods, it is important to identify a more sustainable alternative energy source to rural Kyrgyzstan.

Naturally, any technical solution (e.g., integrating a high share of solar thermal into a community-owned heating plant, thermo-siphon systems, micro digesters for biogas production, etc.) will always cost money. Moreover, meeting that high heat demand with renewable energies costs money as it requires a bigger/larger system supply side. However, the local circumstances (i.e., limited knowledge, lack of energy policies, lack of income, etc.) do not allow through implementation. Hence, there is a need to identify multidimensional/multi-stage solutions to establish sustainability in rural Kyrgyzstan.

The recent literature identified that solar energy has a remarkable impact on Kyrgyzstan. It can be seen from Figure 12f that Kyrgyz territory receives a high amount of solar irradiation which is 60% higher compared to some European countries [42]. Mehta et al. [43] described a technical assessment of solar resources to cover the energy demand for space heating and domestic hot water preparation in single-family homes in rural Kyrgyzstan. The study indicates that there is significant technical potential available for solar-thermal energy for house heating and domestic hot water preparation in Kyrgyzstan. As mentioned previously, hot water is not the key primary need. However, the study proved a high potential for solar thermal-based house heating.

Treichel and Cruickshank [44] examined the technical feasibility and performance of air-based solar collectors in Canada and the United States (cold climates). These results can be transferred to Kyrgyzstan due to its climatic nature. Furthermore, Choudhury and Baruah [45] highlight the importance of solar air collectors for residential space heating.

As mentioned earlier, rural Kyrgyz houses have higher space heating demand due to uninsulated and aged building stock. Theoretically, the integration of renewable energy-based heating supply solutions can eliminate the use of non-sustainable solid fuels and improve sustainability. To overcome this problem, some approaches have used scientific contributions to analyse the impact of insulation on residential space heating. Energy efficiency measures could result in reducing the space heating demand by up to 70% [46] which is a meaningful step before implementing any kind of renewable energy supply. This saving of heating energy could help break down the size of the energy supply system. In that order, Figure 14 represents the solution nexus and describes how to foster sustainable development activities comprehensively and systematically.

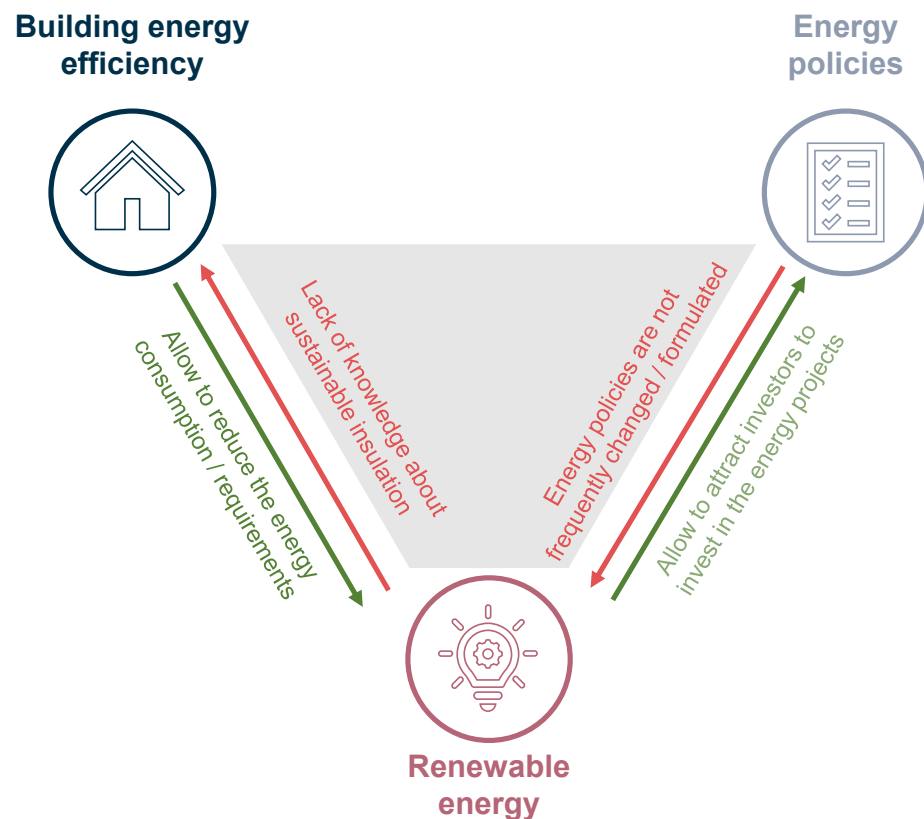


Figure 14. Potential solution nexus to improve rural energy services.

In addition to these technical solutions, energy policy plays a considerable role in Kyrgyz energy sector development. The existing energy policies are one of the key barriers to the development of the renewable energy sector in Kyrgyzstan [47]. Their amendment focuses especially on renewable energy promotion that can help boost the overall progress as it could attract private investors to invest in the green energy sector.

The weaknesses/limitation of the presented article are that it does not promise or propose any particular solution for rural Kyrgyz communities. However, it provides a large picture of what a suitable and potential solution looks like. Naturally, to design and implement any kind of solution, the local circumstances (external and internal factors) should be considered, where the presented research article serves as fundamental input.

6. Conclusions

Access to energy can influence overall society development which is one of the fundamental benchmarks to formulate the Sustainable Development Goals. For more than a decade, Kyrgyzstan has experienced energy crises. In rural Kyrgyzstan, accessing reliable and sustainable energy is an expensive and crucial task for the majority of households and often fails to meet basic energy needs. Hence, it is necessary to enhance rural energy services to improve the livelihoods in rural Kyrgyzstan. However, inadequate energy-related research with a special focus on rural Kyrgyzstan could not provide a detailed assessment of the energy outlook. In addition, the generalised energy pattern or identity for rural settlements is not yet clarified in the available scientific literature. In response to this need, the presented article provides the typical energy identity of rural Kyrgyzstan based on the impressions of the author's on-site visit. The energy pattern was categorised into the three main blocks of energy demand, energy source, and energy carrier. The article concludes by deriving key driving factors for rural energy services. The article articulates the potential and suitable solution nexus to integrate a sustainable energy supply in rural Kyrgyzstan. The rural settlements in Kyrgyzstan look uniform from the socio-economic, geographic,

and demographic points of view. Hence, the presented result can be (partially) transferable to other rural societies in Kyrgyzstan based on the location. Future studies could fruitfully explore the community-based renewable energy generation supply system to evaluate how to mitigate energy crises and foster sustainable energy transition in rural Kyrgyzstan.

Author Contributions: K.M. wrote the manuscript; M.E. and C.T. helped to define the research objective and assisted with proofreading the article; W.Z. provided supervision at all stages of the review. All authors have read and agreed to the published version of the manuscript.

Funding: The work presented in this paper was funded by the Federal Ministry of Education and Research (BMBF) of the Federal Republic of Germany within the CLIENT II funding programme International Partnerships for Sustainable Innovations under the project “ÖkoFlussPlan” (Project ID 01LZ1802A-F). The overall aim of ÖkoFlussPlan is to preserve the alluvial forests along the Naryn River and to implement sustainable energy solutions for the local population.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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